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CHATHAM

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NATURAL ENVIRONMENT RESEARCH COUNCIL

GEOLOGICAL SURVEY OF GREAT BRITAIN

GEOLOGY
OF THE COUNTRY
AROUND
CHATHAM

1954

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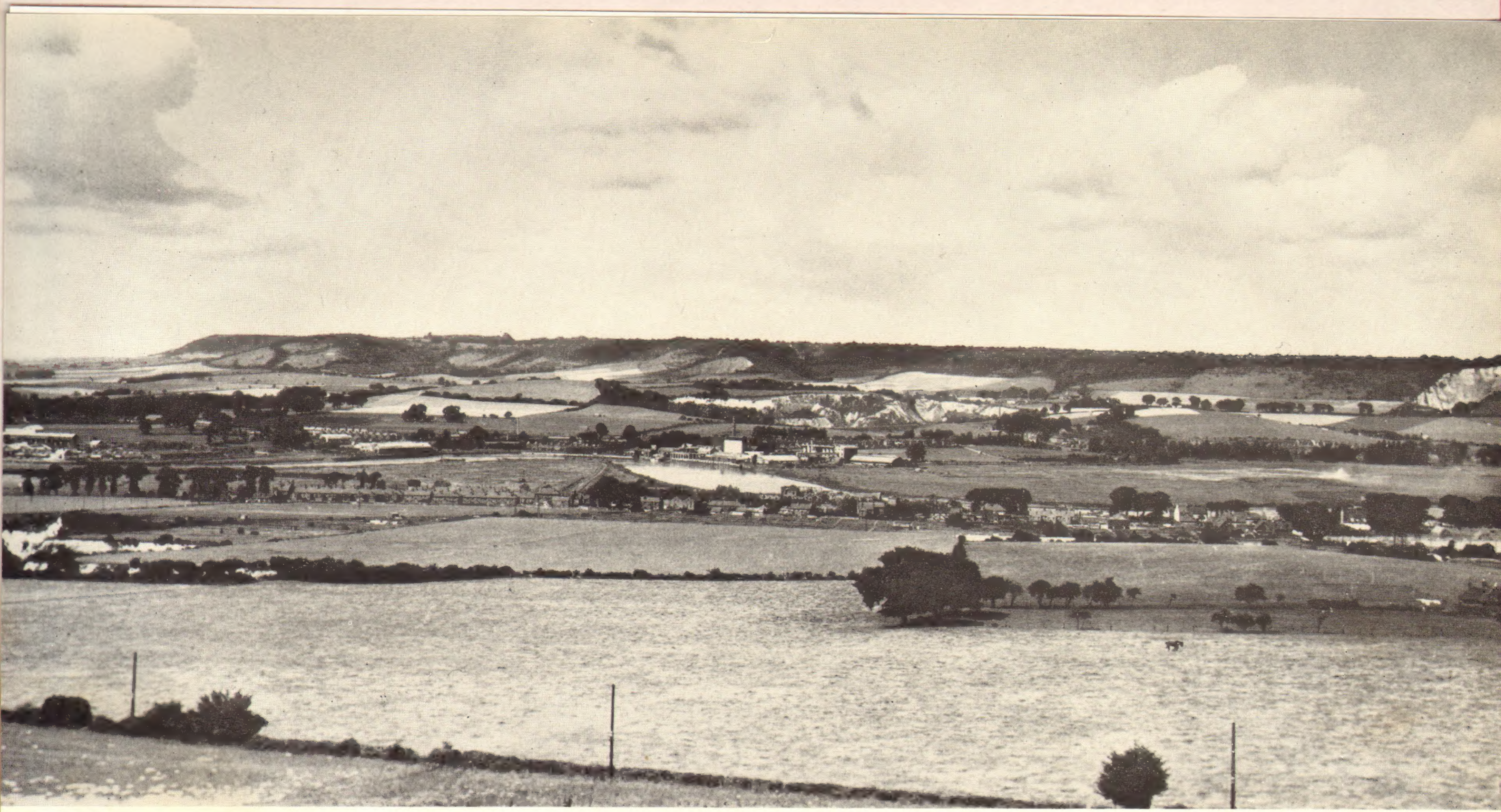

View across the Medway Gap through the North Downs, from near Wouldham (A.7876)

PLATE I
(Frontispiece)

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF GEOLOGICAL SCIENCES

MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN

ENGLAND AND WALES

Geology of the Country around Chatham

(*Explanation of One-inch Geological Sheet 272, New Series*)

BY

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with contributions by
S. Buchan, Ph.D., and F. H. Edmunds, M.A.

Palaeontology by
R. V. Melville, M.Sc.

LONDON
HER MAJESTY'S STATIONERY OFFICE
1954

The Institute of Geological Sciences
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PREFACE

The Chatham district, occupying part of the southern portion of the London Basin, includes the industrialized and naval area of the Medway Towns, and, bordering the Medway Estuary, a wide tract of highly fertile land devoted chiefly to market gardening.

The original geological survey of the area, on the scale of one-inch to one mile, was made largely by W. Whitaker, small tracts also being covered by F. J. Bennett, C. E. Hawkins, T. McKenny Hughes, W. Topley and W. A. E. Ussher. It comprises parts of the Old Series one-inch Geological Sheets 1, 2, 3 and 6, published 1864–8, with revisions 1871–89.

The six-inch scale survey was carried out by Dr. S. Buchan, Mr. H. G. Dines, Mr. S. C. A. Holmes and Mr. J. A. Robbie, in 1937–8, under Mr. C. E. N. Bromehead as District Geologist, who himself had mapped a small tract in the western part of the district during 1920–1.

Numerous references to the district are to be found in earlier Geological Survey memoirs; the whole area is included in the extensive tract described by Whitaker in 'The Geology of the London Basin', published in 1872; and brief references to localities west of the River Medway are to be found in his memoir 'The Geology of London and Part of the Thames Valley', vol. i, 1889. Short accounts of the Cretaceous strata appear in 'The Cretaceous Rocks of Britain', vols. i-iii, 1900–4 by A. J. Jukes-Browne, and Whitaker recorded a number of important well sections in 'The Water Supply of Kent', 1908. He had also planned a 'Part 2' of 'The Geology of the London Basin', to deal with the extensive drift deposits of the area at large, and for which T. McKenny Hughes in particular accumulated much detailed information, but the projected memoir was never completed. Hughes' descriptions of sections now either quarried away or no longer visible, however, proved of considerable value during the six-inch scale survey, and have been freely quoted in the present memoir. Whitaker made a further important contribution to our knowledge of the deeper-seated rocks of the Chatham area in a paper published in the 'Quarterly Journal of the Geological Society' for 1886.

The Medway area has long been a centre of the cement industry, and the resulting large excavations in the Chalk have afforded numerous opportunities for the detailed study of this formation, to which references in geological literature are accordingly numerous, notably in the 'Proceedings of the Geologists' Association', and in the local 'Rochester Naturalist', an outstanding contributor being the late G. E. Dibley.

The present memoir contains, in addition to the accounts by the responsible field officers, sections on Palaeontology contributed by Mr. R. V. Melville and the late A. S. Kennard, notes on the Silurian rocks and fossils from a deep borehole at Bobbing respectively by Professor K. C. Dunham and Dr. C. J. Stubblefield, F.R.S., and on brickearth by Dr. J. Phemister and Professor Dunham. Mr. F. H. Edmunds has edited the memoir, and has also contributed to its more general sections.

Our thanks are given to Mr. A. G. Davis for his assistance in the revision of the nomenclature of early records of Eocene fossils, and for information based on his own collections of fossils; and to Dr. L. F. Spath, F.R.S., who identified many of the ammonites from the Cretaceous strata.

W. J. PUGH
Director

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Exhibition Road
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London, S.W.7
1st March, 1954

PREFACE TO 1971 REPRINT

For this reprint the opportunity has been taken to include fuller particulars of references cited and to correct descriptions of Pleistocene and Recent deposits in Chapters IX and X. Using later borehole information, some revisions have been made to Fig. 3.

By kind permission of the Gas Council, a short summary of the general geological results of the Council's 1959–61 boreholes at Cliffe is now added. It has been specially prepared by Dr. E. R. Shephard-Thorn. Otherwise, no attempt has been made to revise the previous account or to bring the palaeontology up to date.

K. C. DUNHAM
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London, S.W.7
13th January, 1971

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[1] Reference number of photograph in the Geological Survey collection of geological photographs.

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LIST OF SIX-INCH MAPS

The following is a list of the six-inch geological maps included in the one-inch geological map Sheet 272, with the initials of the surveying officers and date of the survey for each six-inch map: the officers are: C. E. N. Bromehead, H. G. Dines, S. Buchan, J. A. Robbie, and S. C. A. Holmes.

Manuscript copies of the maps are deposited for public reference in the library of the Institute of Geological Sciences. They contain more detail than appears on the one-inch map.

ESSEX

84 N.E. (part of)	Stanford-Le-Hope	H. G. D.	1921
84 S.W. (part of)	West Tilbury	H. G. D.	1921
84 S.E. (part of)	East Tilbury	H. G. D.	1921

KENT

4 S.W.	Cliffe Marshes	H. G. D.	1937
4 S.E.	Cooling Marshes	H. G. D.	1937
5 S.W.	Allhallows	H. G. D.	1937
5 S.E.	Grain Marsh	H. G. D.	1937–38
6 S.W.	The Flats	H. G. D.	1938
10 N.E. (part of)	Gravesend	C. E. N. B.	1920
10 S.E. (part of)	Chalk	C. E. N. B.	1920
11 N.W.	Cliffe	H. G. D.	1937
11 N.E.	High Halstow	H. G. D.	1937
11 S.W.	Higham Upshire	H. G. D.	1937
11 S.E.	Hoo	H. G. D.	1937–38
12 N.W.	Lower Stoke	H. G. D.	1937–38
12 N.E.	Wallend	H. G. D.	1937–38
12 S.W.	Hoo Marshes	H. G. D.	1937–38
12 S.E.	Burntwick Island	S. B.	1937
13 N.W.	Sheerness	H. G. D. & S. B.	1937
13 N.E.	Minster Marshes (Scrapsgate)	S. B.	1937
13 S.W.	Queenborough	S. B.	1937
13 S.E. (part of)	Minster	S. B.	1937
18 N.E. (part of)	Cobham	C. E. N. B. & H. G. D. S. C. A. H.	1921 1938
18 S.E. (part of)	Upper Halling	C. E. N. B. S. C. A. H.	1921 1938
19 N.W.	Strood	H. G. D.	1937
19 N.E.	Chatham	H. G. D. & S. B.	1937
19 S.W.	Halling	S. C. A. H.	1938
19 S.E.	Luton	S. C. A. H.	1938
20 N.W.	Lower Rainham	S. B.	1937
20 N.E.	Upchurch	J. A. R.	1937
20 S.W.	Rainham	J. A. R. S. C. A. H.	1937 1938
20 S.E.	Newington	J. A. R.	1937
21 N.W.	Iwade	S. B.	1937
21 N.E. (part of)	Elmley Marshes	S. B.	1937
21 S.W.	Kemsley	J. A. R.	1937

21 S.E.		Conyer	S. B. & J. A. R. ..	1937
30 N.E.	(part of)	Birling	C. E. N. B. .. .. S. C. A. H.	1921 1938
31 N.W.	(part of)	Snodland	S. C. A. H.	1938
31 N.E.		Lidsing	S. C. A. H.	1937
31 S.W.	(part of)	Aylesford	S. C. A. H	1937–38
31 S.E.	(part of)	Boxley	S. C. A. H.	1937
32 N.W.		Bredhurst	S. C. A. H.	1937
32 N.E.		Borden	J. A. R.	1937
32 S.W.	(part of)	Thornham	S. C. A. H.	1937
32 S.E.	(part of)	Bredgar	J. A. R.	1937
33 N.W.		Sittingbourne	J. A. R.	1937
33 N.E.	(part of)	Green Street	J. A. R.	1937
33 S.W.	(part of)	Milsted	J. A. R.	1937
33 S.E.	(part of)	Lynsted	J. A. R.	1937

Chapter I

INTRODUCTION

THE CHATHAM DISTRICT lies within the county of Kent but, north of the large area occupied by estuary-waters of the Thames within one-inch Sheet 272, is included also a small part of land in the county of Essex. A considerable part of the area of this map-sheet is occupied by part of the River Thames estuary and by the estuary of the River Medway.

Chatham, the most important town of the district, lies on the east bank of the Medway, and is continuous with the ancient city of Rochester, built on Watling Street where it crosses the river. Strood, on the west bank of the Medway opposite Rochester, and Gillingham, continuous with Chatham on the east, complete a compact group of Medway towns. Other towns of the area are Sheerness, at the north-west tip of the Isle of Sheppey, and Sittingbourne.

Agriculture constitutes one of the most important of the local industries, and includes mixed farming on the higher ground of the southern part of the area; market gardening on the lower slopes, with their rich and easily-worked soils of brickearth and of the Lower Eocene formations; and fruit growing, Sittingbourne being the centre of a big fruit district. Extensive spreads of brickearth have also given rise to brickmaking, one of the oldest of the industries of the area, with Sittingbourne, Lower Halstow and Hoo as the chief centres. Many large chalk quarries, some now abandoned, have been worked for the manufacture of cement.

The general geology of the district is shown on the geological sketch-map, Fig. 1. The Chalk escarpment is present in the south-west corner of the district, where it is breached by the River Medway, but it lies mostly just south of the area, striking W.N.W. to E.S.E.; the level of the ground being in consequence over 600 ft above O.D. at Bluebell Hill, south of Chatham, and decreasing to just over 200 ft north-east of Lynsted. From the southern boundary of the sheet, the Chalk area slopes gently north-east to the marshes of the Medway estuary and the Swale. The Chalk dip-slope—part of the North Downs—which thus occupies the southern half of the district, is much dissected by dry valleys which course north-east, with the important exception of the Luton valley, which trends N.W. to join the Medway valley at Chatham.

Of this district McKenny Hughes (*in* Whitaker 1872, p. 360) remarks 'There is a curious feature in the Chalk-district south of Chatham. The country slopes northward from the escarpment with the usual characteristics, viz., rounded hills, covered with woods or good corn-land on the top, where the "clay-with-flints" lies, but bare and sterile on the flanks; and cut up by deep branching valleys with their narrow gravel-flat at the bottom. But there is a second escarpment running S.E. from Chatham, parallel to the true escarpment, for about 3½ miles . . . From this second escarpment there is a steady slope to within about three-quarters of a mile of the alluvium, where the Thanet Beds come on.' Of the tract eastward of the Medway he wrote: 'The hills in this part of the Tertiary district are generally of small elevation except when capped by clay, which, resisting denudation better than sand, has often preserved a complete set of the Oldhaven Beds and the bottom of the London Clay in a small hill, rising from a flat or gently undulating country of the Thanet Beds'.

The Medway valley through the Chalk Downs is the most striking physical feature of the district; its character is illustrated by Plate I. About 2½ miles wide and mostly floored by alluvium near Snodland, the valley narrows downstream, to not much more than a quarter of a mile wide at Rochester, where the Chalk hills and the east bank rise straight from the river. Below Rochester the river flows through an extensive flat, cut up by small channels and creeks, and bounded by low round hills of Tertiary strata, many capped by terraced river gravel of an ancestral river.

The Swale, between Sheppey and the mainland, has been regarded as an old course of the Medway, but this hypothesis receives little support from borings (*see* p. 144).

A relatively small but pronounced Eocene escarpment is formed by the Woolwich Beds and the Blackheath and Oldhaven Beds capped by London Clay. A remnant of this scarp occurs between the Medway and the Thames running west-north-west about 1½ miles north of Strood. The ground to the north reaches a height of over 200 ft at Great Chattenden Wood and Lodge Hill and slopes gently to the marshes at Allhallows.

Other remnants of the Eocene scarp are preserved in the hill on which Upchurch is built, and again north-east of Newington. The ground at the latter attains a height of 200 ft and slopes gently to the marshes north of Iwade. East of Sittingbourne are two small scarps formed by the Woolwich Beds and the Blackheath Beds. The two small hills, capped by Woolwich Beds S. and S.E. of Upchurch as also the two N.N.W. and N.N.E. of Green Street are outliers from the Eocene scarp. The high ground of the part of the Isle of Sheppey which reaches over 200 ft above O.D. is composed of London Clay capped by Bagshot Beds.

The natural drainage is simple. The Thames, in its lower reaches, crosses the north-west corner of the area, and the Medway enters the area from the south 1½ miles from the western boundary and flows northwards for about 5½ miles when it trends north-eastwards as far as Rochester, then takes a general east-north-easterly direction to the sea at Sheerness. The Swale, which separates the Isle of Sheppey from the Mainland, courses south-east for 5 miles from near the mouth of the Medway and then eastwards to join the sea north of Faversham, eastward of the area. Of three small streams in the eastern part of the mainland, one rises from the Thanet Beds north of Newington and flows to the tidal flats at Lower Halstow; Milton Creek, although tidal, is fed by springs from the Chalk in Sittingbourne; and the third stream rises as a spring from near the base of the Thanet Beds north of Bapchild and flows by Tonge to join the Swale at Conyer.

Solid rocks coming to crop in the area include: (a) the Folkestone Beds of the Lower Greensand, which occupy half a square mile west of the Medway in the south-west corner of the area and comprise rather fine-grained current-bedded sands, white or yellow in colour; (b) the Gault, covering only 2 square miles, about half of which is hidden by Drift, and forming the low ground below the scarp of the North Downs; (c) the Chalk, with an outcrop covering about 75 square miles, of which about 4 square miles are of Lower Chalk and 6 square miles of Middle Chalk; and (d) Eocene strata covering about 60 square miles,

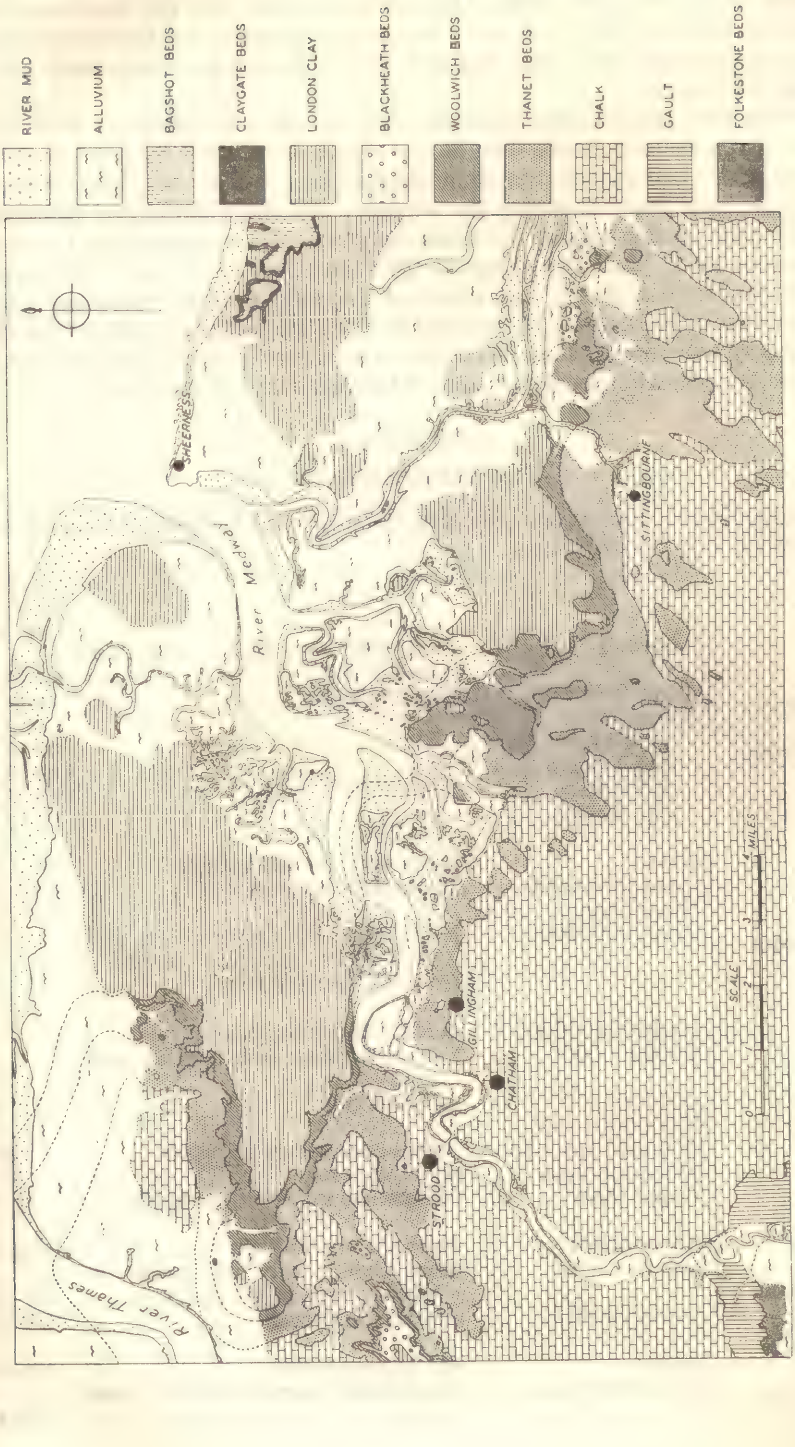

FIG. 1. *Geological sketch-map of the Chatham District*

the two most extensive outcrops being of the Thanet Beds, 22 square miles, and London Clay, 30 square miles. The Woolwich Beds and the Blackheath and Oldhaven Beds are very thin and even absent in places and their outcrops are restricted. Claygate Beds and Bagshot Beds are present over a small area in the Isle of Sheppey.

Of the Drift deposits, the Clay-with-flints covers some 15 square miles of the higher Chalk country, more than half of which is occupied by scrubby woods, the remainder being given over to mixed farming; river terrace deposits occupy relatively small areas adjoining the Medway and the Thames and brickearths cover a considerable area of the lower slopes of the outcrops of the Chalk and the Eocene Beds. Many dry valleys in the Chalk area are floored with a deposit of subangular flint gravel, and much of the solid geology, especially on the lower slopes of the district, is obscured by head deposits, a variable series often of a loamy nature with some flints, but which locally may be mainly sand or mainly clay. Alluvium occupies some 40 square miles of the area.

TABLE OF STRATA

The geological formations indicated by colour and symbol on the geological map, Sheet 272, are as follows:

			Estimated thickness in feet
Recent and Pleistocene	Alluvium	mud, with local beds of peat, silt, and gravel	up to 104
	River Brickearth	silts and clayey traces	up to 30
	River Gravel		
	1st Terrace	sand and gravel	up to 35
	2nd Terrace		up to 10
	3rd Terrace		up to 6
	4th Terrace		up to 6
Recent and Pleistocene	Head	loam, sand, or chalk rubble	up to 30
	Head Brickearth	silts and clayey loam	
	Head Gravel		
	Clay-with-flints	loamy clay with unworn flints, and with various materials derived from the Tertiary Beds	15
Eocene	Bagshot Beds (part)	sands with pebble beds	40
	Claygate Beds	thin alternating beds of clay and sand	20
	London Clay	stiff blue clay	450
	Blackheath and Oldhaven Beds	pebble beds, sands and clays	0–25
	Woolwich Beds	sands and clays	?0–60
	Thanet Beds	fine-grained sands with some clay	70–130
Upper Cretaceous	Upper Chalk	white chalk with flints	about 300
	Middle Chalk	white chalk, hard and rough or blocky; flints in the top 50 ft	180–230
	Lower Chalk	massive tough chalk	175–235
Lower Cretaceous	Gault	stiff blue-grey clay	135–235
	Folkestone Beds	fine-grained current-bedded loose sands	?0–170

The following concealed formations have been proved in borings:

		Estimated thickness in feet
Lower Cretaceous	Sandgate Beds	?0 to 20
	Hythe Beds	?0 to over 100
	Atherfield Clay	?0 to 20
Jurassic	Corallian Beds	Data insufficient for estimates of thickness
	Oxford Clay	
	Kellaways Beds	
	Cornbrash	
	Forest Marble	
	Great Oolite	
Silurian	?Ludlow	
	Wenlock	
	?Llandovery	

J.A.R.

References

Jukes-Browne, A. J. 1900–4. The Cretaceous Rocks of Britain; vol. i (1900), The Gault and Upper Greensand of England; vol. ii (1903), The Lower and Middle Chalk of England; vol. iii (1904), The Upper Chalk of England. *Mem. Geol. Surv.*

Whitaker, W. 1872. The Geology of the London Basin. *Mem. Geol. Surv.*, vol. iv.

Chapter II

STRUCTURAL GEOLOGY AND PRE-CRETACEOUS CONCEALED FORMATIONS

STRUCTURAL GEOLOGY

LITTLE IS KNOWN of the beds beneath the Cretaceous cover, but from the results of seven deep borings (Fig. 2), a general picture of the sub-Cretaceous floor may be constructed. North of a line running approximately along the southern part of the Swale and continuing west-north-west to south of Cliffe, Lower Greensand has been shown to rest directly on Silurian rocks, of Wenlock age at Cliffe, and on possibly Ludlow, but probably earlier Silurian, at Bobbing, N.W. of Sittingbourne. Within a belt about 4 miles wide on the south side of this line Lower Greensand rests on successively younger members of the Jurassic System, while to the south of this again Wealden Beds are developed between the Lower Greensand and the Jurassic strata; thus, in borings at Chatham Dockyard and Gillingham Gas Works, Lower Greensand rests on Oxford Clay, while at Nashenden Pumping Station, south of Chatham, a boring penetrated Lower Greensand and then entered ?Corallian Beds.

The Chatham area may be regarded either as part of the south side of the London Basin or of the northern counterpart of the Wealden Dome. As both these structures are broad and elongated in form, the Cretaceous rocks of the present area have a regional dip of a few degrees mainly to the N.N.E. Both the Cretaceous and Tertiary tracts are, however, modified by comparatively gentle structural lines, along axes approximately W.N.W. to E.S.E. and N.N.E. to S.S.W. Small faults, outlined below, conform with these structures and represent minor adjustments. In the adjacent areas to the west and east the presence of pre-Eocene folds has been demonstrated, notably an anticlinal axis through the Isle of Thanet. In the Chatham area, however, no such folds appear to exist, and the Eocene, wherever present, appears to rest on Chalk of the Coranguinum Zone, and the thickness of the Upper Chalk according to interpretations of borehole records varies little.

The structural features may be interpreted from the contour map, Fig. 3, of the sub-Eocene Chalk platform, prepared from information from well and borehole records.

The general impression gained from this map is one of folds running parallel to the dominant W.N.W. to E.S.E. strike, with E. to W. modifications north-west and north-east of Chatham. Mainly east-south-east of Chatham less pronounced structures trend N.N.E. to S.S.W. to produce small variations in the generally uniform N.N.E. dip.

An anticline through the Chalk area of Cliffe persists E.S.E. beyond High Halstow but changes to an E. to W. trend, and is apparently still present in diminished strength at Grain. Westwards from Cliffe it also becomes E. to W. producing a change of strike in West Kent, and bringing Chalk to the surface at East Tilbury. Another branch of this fold seems to persist northwards from East Tilbury.

Complementary to the Cliffe anticline is a syncline through Higham. To the west this is also E. to W. in trend and a marked change of strike is shown about Higham Upshire; but the Tertiary basin broadens and trends E.S.E. to

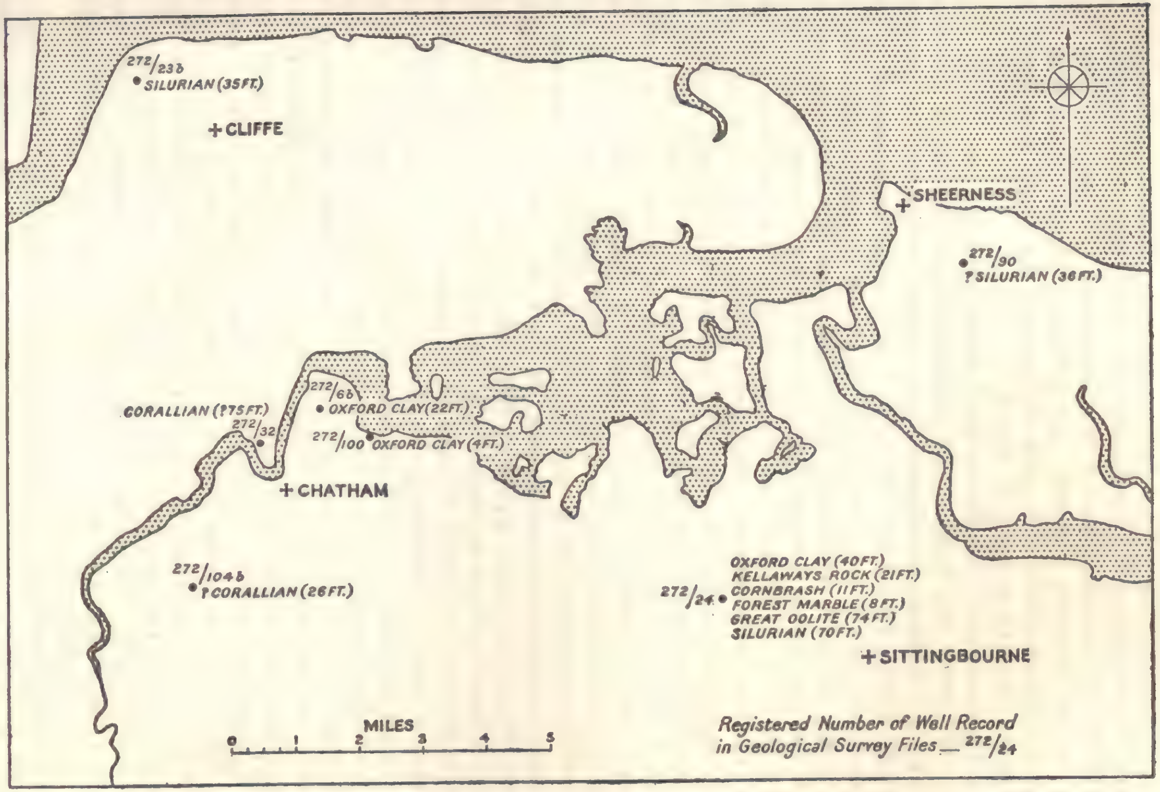

FIG. 2. *Map showing sites of boreholes proving concealed pre-Cretaceous Formations*
The identification of Oxford Clay at 272/100 (Gillingham) is doubtful.

Hoo, beyond which, with increasing depth, it gradually diminishes in importance along the Medway estuary while persisting E.N.E. to Sheerness and beyond. Where both these structures are strongest, the northern-sloping limb is more pronounced than the southern, for example in the steep initial slope, indicated by the close contours, into Cliffe Marshes. There is a similar increase of dip on the corresponding limb of the Higham syncline. Thus the railway-cutting at Higham Station showed the junction of the Thanet Beds and Chalk with an apparent N.W. dip increasing from 2° to 6° (Whitaker 1872, p. 72; 1889, p. 121), but the true dip is more northerly and somewhat steeper. Priest and Epps (1935, p. 61) contrast these dips with the general dip in the area north-east of Shorne, reckoned to be about 2° N.N.E.

Along approximately W.N.W. to E.S.E. lines there are three further folds of some importance and other minor folding. An anticline along the Luton valley, S.E. of Chatham, is indicated by a number of features. At Darland, Chalk of the Planus Zone (*see* p. 44) dips 3° S.S.W. On the south side of this valley, south of Upper Luton, chalk of the same zone occurs at a comparatively high level. In the valley bottom Middle Chalk may abut against the under surface of the drift where this may have cut out the basal Planus Zone, locally some 10 to 20 ft thick. Calculation from the well-records at the Luton Pumping Station (272/9)[1] confirms that but little Upper Chalk floors the valley in this area. Furthermore, on the south-east side of Chatham the chalk just west of the railway bridge at the end of the High Street is proved to belong to low Planus Zone (*see* p. 43), so that Middle Chalk cannot be far beneath the surface hereabouts. The Cortestudinarium Zone, in pits on the east side of the Luton valley (p. 45) and on the west at Chalk Pit Hill, Chatham (p. 45), is also elevated to an abnormal level by reason of this flexure. North-westwards the Luton valley is approximately continuous with the bend of the Medway forming Limehouse Reach, a feature probably influenced by the same folding and accounting for the outcrop of chalk of the Cortestudinarium Zone here. The second fold is a syncline which Hughes (*in* Whitaker 1872, p. 350) suggested runs from Stockbury to Rainham. Though in fact somewhat closer to Hartlip, there is some evidence for this fold in the steepening N.E. dips at the Thanet outcrop. The third small strike fold is east of Sittingbourne, where Woolwich Beds capping the hill about 1¼ miles N.N.W. of Green Street dip gently to the south, being on the south limb of a gentle anticline of a very limited extent. It is indicated on the eastern of the two sections shown on the geological map, Sheet 272, which also shows that the Tertiary Beds to the south rest in gentle synclines separated by gentle anticlinal rolls where Chalk is at the surface; these are, however, not strong enough appreciably to effect the spacing of the contours of the sub-Eocene Chalk surface (*see* Fig. 3). The contour spacing shows a flattening of the N.N.E. dip around Minster in the Isle of Sheppey. The general tendency for the Thanet Beds to rest on the Chalk in gentle synclinal hollows seems to hold throughout the district.

Strike-folding is indicated, in addition, by an increase of the dip about Cuxton and by a fairly marked steepening at the southern edge of the Chalk outcrop and along the escarpment. Recorded dips at the large Burham chalk quarries half a mile S.W. of Bluebell Hill show the N. to N.E. dip to increase

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[1] Numbers in brackets are registered numbers of borehole records in the Geological Survey collection.

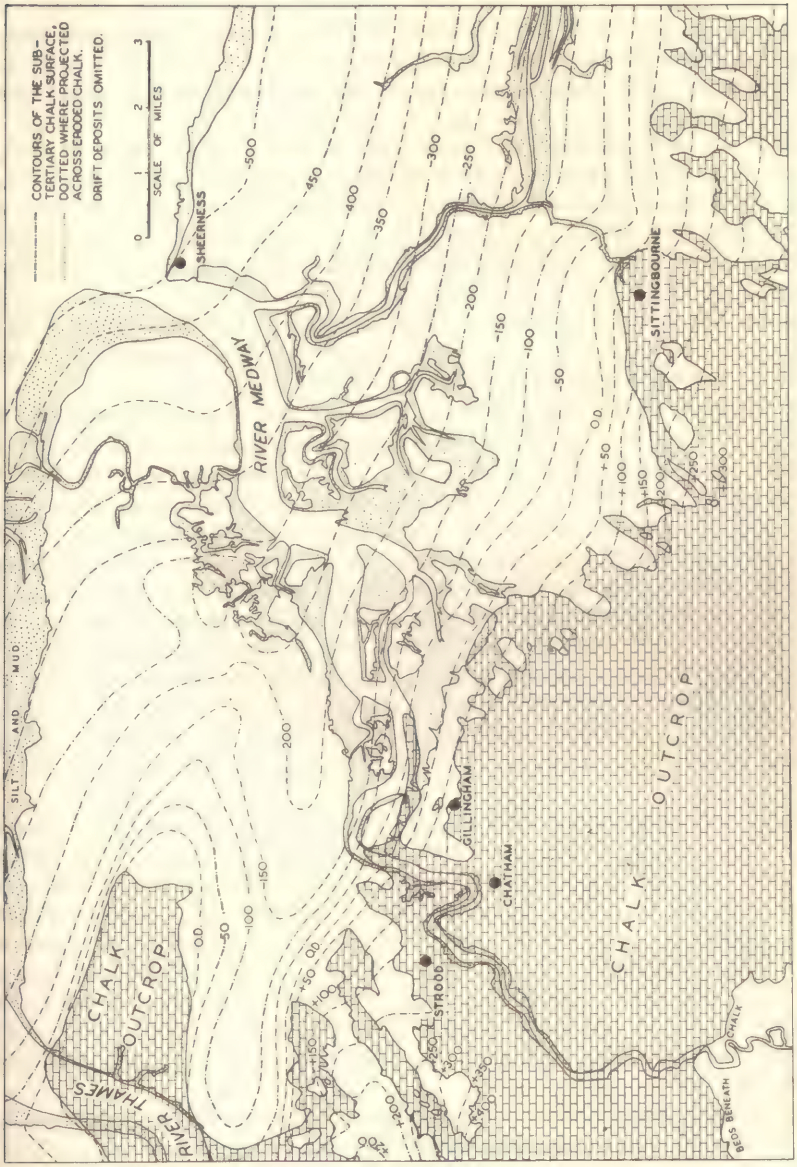

FIG. 3. *Map showing contours of the sub-Eocene surface of the Chalk*

from 2° to 5° or more; Hughes (*in* Whitaker 1872, p. 29) noted 8° locally, and Hood noted 6° (1884, p. 62).

Lastly, in the area occupied by the Upper Chalk east of the Medway, variations in the direction and amount of dip together with features in the distribution of the fossil zones indicate very gentle folding approximately parallel with the strike. The most important of these flexures crosses Walderslade Bottom (*see* p. 43), and there may be other examples, for instance across the valley below Gibraltar Farm. Folding also occurs on the border of the sheet south of Lower Cox Street.

A syncline through Shorne is occupied by the Tertiary mass, capped by London Clay, which extends N.E. from the western edge of the area. From Shorne northwards the basin appears to fade out, but it should be said that S. W. Wooldridge (1923, p. 177) and H. J. W. Brown (1925, p. 441) consider that the Shorne syncline is continuous with another extending N.E. to Allhallows, with a parallel syncline N.E. along the Medway.

Between the Shorne syncline and the Medway at Rochester there is gentle folding on N.N.E. to S.S.W. lines, mainly anticlinal but with apparently a small syncline crossing the Watling Street east of Park Pale.

The Medway itself follows approximately the line of an important anticline in the Chalk. This was recognized by Hughes (*in* Whitaker 1872, p. 350) and by Dibley (*in* Bennett 1904, p. 463), but others have regarded the Medway above Rochester as flowing in a syncline and indeed Wooldridge (1923, p. 179; 1926, p. 185) postulated a monocline extending south from Essex to the Medway gap; such a structure, however, appears to be discordant with the general structural pattern. The anticlinal structure of the Medway valley does not persist beyond Rochester. It is confined to the Chalk tract and its axis probably trends rather N.N.E. than N.; on the east side of the Medway, therefore, the dips are generally more easterly around Wouldham and Borstal. On the west side of the Medway, Chloritic Marl at the base of the Lower Chalk dips 7° N.N.W. at a point in the Holborough Cement Works Pit half a mile N.W. of Snodland Church. In a large pit below Frindsbury, Hughes recorded N.N.W. dips.

No evidence has come to light that the north-easterly course of the Medway from above Cuxton has any structural significance, but east of the Medway the general grain of the topography may be generally associated with slight folding along the main dry valleys. Hughes suggested that a syncline running N.N.E. to S.S.W. may extend from the Medway through Half Acre and Motley Hill to Rainham. There is some evidence for this but the fold does not appear to persist as far as Rainham. East of Rainham a broad syncline extends from Hartlip to the marshes at Lower Halstow and a general anticlinal area with minor modifications occupies the ground east of Stockbury and down through Sittingbourne and Milton.

Hughes described a probable line of upheaval in the valley east of Stockbury, as far as Key Street. Borehole information indicates an accentuation N.N.E. through Murston of the gentle synclinal shown by the Thanet Beds outcrops between Tunstall and Bapchild. Some of these structural lines correspond with Hughes' account in general.

Faulting is unimportant. On the east side of the Medway valley, both at the scarp and in exposures on the dip-slope, numerous small fractures can be traced in the Chalk, mainly at the horizons of the Melbourn Rock and of the rocky bands at the base of the Upper Chalk. These faults are usually at right angles to the strike and have displacements up to about 15 ft. Priest (1924, p. 78) records small-scale folding and faulting in the Eocene Beds at Salters Cross, on the Watling Street, 1 mile west of Strood, which he ascribes to deeper-seated structures, but these disturbances are probably superficial only. In the railway-cutting north-north-east of Keycol Hill a fault, trending approximately N. to S., has a downthrow of 6 ft to the east, affecting the London Clay and modifying its outcrop a quarter of a mile to the south, where the fault swings a little west of south and apparently dies out north of Watling Street.

S.C.A.H.

SILURIAN STRATA

Within the limits of the present area six borings have certainly proved rocks of pre-Cretaceous age, which are not exposed at surface (Fig. 2). Three reached the Palaeozoic, but cores were only taken at Bobbing.

Silurian rocks were proved in the deep boring for water at Cliffe Marshes (272/23b), and also in a coal exploration bore at Bobbing (272/24). Probable Silurian is recorded from the Sheerness East Waterworks boring (272/90). The Cliffe bore passed at 1037 ft from Lower Greensand (Whitaker 1908, pp. 108, 382) into a dark grey mudstone. Fossils from 1063 ft down, according to Dr. C. J. Stubblefield, comprise *Atrypa reticularis* (Linné), *Leptelloidea* (*Leangella*) *segmentum* (Lindström) and crinoidal columnals indicating Wenlock age (*see* Stubblefield *in* Bullard and others 1940, p. 89). The Sheerness boring was made by percussion and the lowest 36 ft below 1348 ft, was represented entirely by finely crushed dark bluish shale or slate, generally regarded as of Silurian age (Lamplugh, G. W., F. L. Kitchin, and J. Pringle 1923, p. 183). The Bobbing bore passed through Cretaceous and Jurassic rocks and, at 1190 ft depth, penetrated 70 ft into steeply-dipping, hard dull grey micaceous sandy shale with a slight purplish tinge in places, which had been identified as being almost certainly Silurian and possibly of Ludlow age. The shale had as a parting a six-inch band of quartzitic greywacke at 1231 ft (Lamplugh and others 1923, p. 159). There was a strong unconformity between the base of the Jurassic rocks and the shales. It was estimated that a true thickness of about 20 ft of the formation had been proved but it was possibly somewhat less.

Dr. C. J. Stubblefield has re-examined the fossils collected from the depths 1190 ft to 1250 ft and reports that they comprise:

'Plant remains (slender carbonised threads up to 5 cm long and 1 mm in diameter, bifurcating frequently to become 0·5 mm in diameter); these are considered by Professor W. H. Lang, F.R.S., "more likely to be an algal thallus than a more advanced plant"; he assigns no name to the material which includes the *Monograptus ?* of Lamplugh and others (1923); crinoid stem-columnals, *Plumulites sp.* (named and cited by T. H. Withers 1926, p. 70); ramose Trepostomatous Polyzoan (possibly a member of the Trematoporidae according to Dr. K. P. Oakley); *Chonetes* cf. *novascoticus* Hall [the *Orthis* (*Dalmanella ?*) *sp.* of Lamplugh and others (1923)]; fragment of rounded fascicostate brachiopod "ribbing"; lamellibranch fragments including the posterior end of a *Nuculites*-like shell; an orthocone nautiloid, annelidan burrows, and a small Trilobite fragment which may be part of the thorax or pygidium of a *Homalonotus* s. lato. Professor Lang was able to offer no opinion from the plant evidence as to age; and the animal remains, other than the *Chonetes*, are likewise unhelpful. This latter is represented by two examples with one in counterpart (J. M. 1648–9, 1650), but both preserved as siltstone-moulds of ventral valves respectively 5 and 6 mm wide and 3 and 3½ mm long. Each shows radial costae of two sizes, a single larger medial costa and the remainder distributed in the ratio of 7 to 1 mm at the front of the shell; some of these latter are slightly thickened but on no regular plan and on the postero-lateral part of the shell they give place to concrescent growth ridges which indicate a slightly auriculate hinge margin. The presence of a medial costa is a feature of several Strophomenacean lineages and the generic assignation was uncertain until immersion in clove oil revealed the presence of small dental plates and of at least three pairs of spines along the hinge line, thus confirming a suggestion previously made by Professor O. T. Jones, F.R.S., that one spine was present and that the genus might be *Chonetes*. Among the species of this genus showing a strong medial costa, the Bobbing examples agree best with *C. novascoticus* which in America ranges from the Upper Clinton to the Lower Devonian; in Britain a new variety *missendenensis* was described by S. H. Straw (1923, p. 117, pl. ix, fig. 11) from the Downtonian in a borehole at Little Missenden. The representatives found in the Upper Clinton of Maryland are stated by C. K. Schwarz (1923, p. 433) to be smaller than those from the later horizons in Nova Scotia and Indiana but even in Maryland the specimens are larger than at Bobbing, being 10 mm wide and 6 mm long. The Devonian examples from Maine average 10 by 15 mm and small specimens are 6 by 10 mm (*see* H. S. Williams 1916, p. 46). The Little Missenden form is also large, 13 by 23 mm. It would seem therefore, if relative size may be taken as a criterion, that a Clinton age is the nearest parallel and in this connexion it may be recalled that the Bobbing plant is not unlike one of the original illustrations of a Clinton plant, *Buthotrepis gracilis* Hall (1852, pl. v, fig. 1a). The Clinton was correlated with the Upper Llandovery to Woolhope by R. S. Bassler (1915, pl. iv) so that it is concluded that the Bobbing strata may be within that range.'

It would appear from the above that the Silurian age of these sediments is confirmed though they may be Wenlock or even Upper Llandovery.

The following descriptions of rock specimens have been contributed by Dr. K. C. Dunham:

(a) Specimen containing '*Homalonotus*'. The rock is a grey gritty micaceous siltstone, composed of angular quartz grains averaging 0·01 mm, and flakes of white mica up to 2 mm across in a matrix of finely-divided clay minerals of moderate birefringence containing some calcite ($\omega = 1{\cdot}657$) and also idiomorphic crystals of a carbonate of refractive index near 1·695 (an ankerite). Abundant strings of idiomorphic pyrite crystals are present, individual cubes seldom exceeding 0·005 mm. The fossil appears to be preserved in reddish brown limonite, which also encloses some quartz grains. (J.M. 1638: E21543.)[1]

(b) 'Limestone' from 1192 ft. A grey ankeritic sandstone, composed of subangular quartz grains of about 0·1 mm average size, rare grains of oligoclase and shreds of white and brown micas, in a carbonate cement. The ordinary-ray refractive index of the carbonate ranges from 1·694 to 1·700, indicating ankerite with approximately 25 to 30 per cent ferrodolomite ($FeCO_3.CaCO_3$). Fossil fragments scattered through the rock are also preserved in ankerite. Veinlets of calcite with $\omega = 1{\cdot}657$ cut across the rock. Accessory minerals include abundant pyrite in strings of tiny cubes; zircon, and tourmaline. (J.M. 1651: E21545.)

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[1] Following the collector's numbers, those preceded by 'E' refer to specimens and thin sections in the Petrographical Collections.

(c) 'Quartzite with pyrite' from 1234 ft. A black ankeritic quartzite, richly impregnated with coarse pyrite. In thin section the rock is composed of subangular quartz grains, well sorted, averaging about 0·1 mm, cemented with a secondary quartz, the presence of which is evident from inclusions, probably of clay minerals, which mark the outlines of the original grains. Fossil remains, preserved in ankerite having $\omega = 1{\cdot}697$, or in limonite, are scattered through the rock, and there are small areas of the carbonate, in places showing rhombic crystal outlines, which do not obviously represent organic remains. Minor constituents of the rock include muscovite, a brown biotite-like mica (probably altered), tourmaline, zircon, and a few rounded grains of ?magnetite. (J. M. 1639: E21544.)

(d) 'Limestone' from 1239 ft. A grey gritty ankerite-siltstone, similar to 21545 but containing a smaller proportion of quartz grains, and a higher proportion of fine-grained ankerite. Flakes of muscovite, visible in the hand specimen, are present and there are dark areas in which pyrite forms rims to the quartz grains and ramifying veinlets on a minute scale. The matrix of the rock has a faint brown colour, probably due to slight oxidation of the ankerite. (J.M. 1637: E21546.)

JURASSIC STRATA

GREAT OOLITE. Of the 154 ft of strata, proved in the Bobbing bore between the Lower Greensand and the Silurian, the bottom 74 ft have been assigned to the Great Oolite. They comprise 59 ft of yellowish oolitic limestones of variable texture and compact cream-coloured limestone with, below, 15 ft of grey calcareous loam, muddy sandrock, crystalline limestones and a layer of calcareous grit at the base. Small pebbles of slate were present in the lower part.

The list of fossils given by Lamplugh, Kitchin and Pringle (1923, p. 158) can be amended in the following details:

1127–9 ft. For *Lima* (*Radula*) *cardiiformis* Morr. and Lyc. [?J. Sow.] read *Lima* (*Plagiostoma*) *subcardiiformis* Greppin. For *Trigonia moretoni* Lyc. read *Myophorella* (*Vaugonia*) *moretoni* (Morris and Lycett).

1132–40 ft. For *Mytilus furcatus* Goldf. read *Brachidontes* (*Arcomytilus*) *bathonicus* (Morris and Lycett).

1155 ft. For *Pseudotrapezium* cf. *bathonicum* (d'Orb.) [immature] read *Opis* (*Coelopis*) *pulchella* Lycett *ex* d'Orbigny. Add *Anisocardia* (*Antiquicyprina*) *sp. juv.*

1164–72 ft. For *Gervillia sp.* read *Gervillella monotis* (J. A. Eudes-Deslongchamps). For *Mytilus sublaevis?* J. Sow. read *Mytilus* (*Falcimytilus*) *sublaevis* J. de C. Sowerby.

1175–7 ft. For *Lithodomus inclusus* Morr. and Lyc. [?Phill.] read *Lithophaga sp.* (crypt).

Special attention may be drawn to the specimen of the calcareous alga *Solenopora* cf. *jurassica* Nicholson recorded from 1175–7 ft. This retains its original beetroot-coloured tint. In the Jurassic, this genus is known from the Great Oolite of Gloucestershire and the Corallian Beds of Wiltshire and Yorkshire, as well as from the Bathonian, Oxfordian and Portlandian of France.

FOREST MARBLE. A thickness of 8 ft of rather coarse yellow and compact blue-black oolitic limestones with dark grey calcareous loam, proved at Bobbing.

is assigned to the Forest Marble. The following corrections may be made in the names of fossils previously recorded (Lamplugh and others 1923, p. 157):

1110–2 ft. For *Terebratula marmorea* Oppel read *Epithyris* cf. *oxonica* Arkell. For *Astarte sp.* [T] read *Eomiodon* aff. *fimbriatus* (Lycett).

These alterations strengthen the comparison made by Arkell (1933, p. 321) between the Forest Marble of Kent and the lower part of the Forest Marble (Kemble Beds) of North Oxfordshire.

CORNBRASH. A thickness of 11 ft of yellowish oolitic rubble, partly limestone and partly clay, overlain by a slightly greater thickness of dark grey and olive-coloured oolitic clay and marlstone occurred in the Bobbing bore. Re-examination of the fossils has rendered possible the recognition of both Lower and Upper Cornbrash. Although the line of division cannot be precisely drawn, it apparently lies between 1103 and 1108 ft and probably above 1105 ft.

Lamplugh, Kitchin and Pringle's list of fossils (1923, p. 157) can be corrected as follows:

1098 ft. *Pseudomonotis* cf. *echinatus* (J. Sow.) is intermediate between *Meleagrinella echinata* (W. Smith) and *M. braamburiensis* (Phillips) as re-interpreted by Douglas and Arkell (1932, p. 163).

1100 ft. For *Pecten* (*Syncyclonema*) *demissus* Phill. read *Entolium corneolum* (Young and Bird). For *Macrocephalites* cf. *compressus* (Waagen) read *M. sp. indet.*

1102 ft. For *Modiolus lonsdalei* Morr. and Lyc. read *M.* cf. *imbricatus* J. Sowerby.

1103–8 ft. (Upper Cornbrash). For *Microthyris lagenalis* (Schloth.) read *Microthyridina* cf. *lagenalis* and *M. sublagenalis* (Davidson). For *Ornithella obovata* (J. Sowerby) read *Digonella siddingtonensis* (Walker).

1103–8 ft. (Lower Cornbrash). For *Anabacia complanata* (Defr.) read *Chomatoseris porpites* (W. Smith). For *Microthyris lagenalis* read *Obovothyris sp.* For *Pleuromya recurva* (Phill.) read *P. uniformis* (J. Sowerby). For *P. securiformis* (Phill.) read *P. subelongata* (d'Orbigny). For *Pseudomonotis echinatus* (J. Sow.) read *Meleagrinella echinata* (W. Smith).

1105–7 ft. For *Terebratula intermedia* J. Sow. read *Cererithyris* cf. *intermedia*. Add *Obovothyris sp.*

KELLAWAYS BEDS. Resting on the Cornbrash at Bobbing are some 21 ft of brown ironshot marlstones with alternations of ferruginous marly clay and some dark grey oolitic clay. The *Rhynchonella varians* (Schloth.) of Lamplugh, Kitchin and Pringle (1923, p. 156) may now be recorded as *Rhynchonelloidella sp.* Their *Pleuromya recurva* (Phill.) is *P. uniformis* (J. Sowerby) and their *Pseudomonotis sp. nov.* is *Meleagrinella braamburiensis* (Phillips).

OXFORD CLAY was proved to be 40 ft thick at Bobbing, where it immediately underlies the Lower Greensand. The ammonites have been re-examined by Dr. L. F. Spath, who reports *Kosmoceras* cf. *hoplistes* (S. Buckman) and *Lunuloceras brighti?* (Pratt) as indicating the Ornatum Zone at 1036 and 1041 ft (immediately beneath the Lower Greensand); and *Erymnoceras sp.* (aff. *coronatum?* Bruguière sp.) with *Kosmoceras* (*Gulielmites*) *sp.* as indicating the Coronatum Zone at 1059–76 ft. This confirms the statement by Lamplugh, Kitchin and Pringle (1923, p. 155) that all but the lower part of the Oxford Clay has here been removed by (pre-Cretaceous) erosion.

At Chatham Dockyard a boring (272/6b) passed through Lower Greensand into hard stiff clay with nodules, identified as Oxford Clay, proved for 22 ft without being bottomed. A borehole at Gillingham Gasworks (272/100a) passed from Lower Greensand into a hard green clay believed on lithological evidence to be Oxford Clay.

CORALLIAN rocks have been proved in a bore at the Frindsbury Cement Works (272/32c). This did not penetrate to the Oxford Clay, the bottom 40 ft being in hard oolitic limestone with about 7 ft of hard blue pisolitic and slightly ferruginous clay and shale at the top[1].

Some sand and grey clayey material also yielded Corallian fossils. Some 35 ft of beds above these which are in turn overlaid by the Lower Greensand at 813 ft are poorly recorded, but hard clayey mudstones with rock beds may be separate from the upper beds of the Corallian. In a borehole at Nashenden Pumping Station (272/104b), beneath a well-defined base of the Lower Greensand at 760 ft, come 26 ft of blue compact calcareous clays and mudstones with layers of sideritic sandstone at the top and beds of whitish rock which is seen under the microscope to be a fine calcite mudstone.

Specimens from these beds in the Geological Survey collections indicate certain similarities with the upper part of the Corallian Beds in Frindsbury and other Kent boreholes, in that they contain ferruginous bands in the clay; and they are therefore provisionally referred to this formation.

J.A.R., R.V.M.

REFERENCES

ARKELL, W. J. 1933. *The Jurassic System in Great Britain.* Oxford.

BASSLER, R. S. 1915. Bibliographic Index of American Ordovician and Silurian Fossils, vol. 2. *Bull. U.S. Nat. Mus.*, No. 92.

BENNETT, F. J. 1904. Excursion to Cuxton. *Proc. Geol. Assoc.*, vol. xviii, p. 463.

BROWN, H. J. W. 1925. Minor Structures of the Lower Greensand of West Kent and East Surrey. *Geol. Mag.*, vol. lxii, p. 439.

BULLARD, E. C., T. F. GASKELL, W. B. HARLAND and C. KERR-GRANT, and others. 1940. Seismic Investigations on the Palaeozoic Floor of East England. *Phil. Trans. Roy. Soc.*, Series A, No. 800, vol. 239, p. 89.

DOUGLAS, J. A., and W. J. ARKELL. 1932. The Stratigraphical Distribution of the Cornbrash: II, the North-Eastern Area. *Quart. Journ. Geol. Soc.*, vol. lxxxviii, p. 112, pls. X-XII.

HALL, J. 1852. *Natural History of New York* '*Palaeontology*', vol. ii. Albany.

HOOD, A. W. 1884. The Chalk of the Medway Valley. *Rochester Naturalist*, vol. i, p. 57.

LAMPLUGH, G. W., F. L. KITCHIN, and J. PRINGLE. 1923. The Concealed Mesozoic Rocks in Kent. *Mem. Geol. Surv.*

PRIEST, S. 1924. Excursion to Cobham and Strood. *Proc. Geol. Assoc.*, vol. xxxv, p. 77.

—— and F. J. EPPS. 1935. Field Meeting at Higham and Shorne. *Proc. Geol. Assoc.*, vol. xlvi, p. 61.

SCHWARZ, C. K. 1923. *Maryland Geological Survey Silurian:* Baltimore.

STRAW, S. H. 1933. The Fauna of the Palaeozoic Rocks of the Little Missenden Boring. *Sum. Prog. Geol. Surv.* for 1932, pt. 2, p. 112.

WHITAKER, W. 1872. The Geology of the London Basin. *Mem. Geol. Surv.*, vol. iv.

—— 1889. The Geology of London and of part of the Thames Valley, vol. i *Mem. Geol. Surv.*

—— 1908. Water Supply of Kent. *Mem. Geol. Surv.*

WILLIAMS, H. S. 1916. Fauna of the Chapman Sandstone of Maine. *U.S. Geol. Surv. Prof. Paper*, No. 89.

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[1] Dr. L. F. Spath has identified a Corallian ammonite as *Amoeboceras* (*Prionodoceras*) *sp.* from these beds at 853¾ ft and a probable Corallian Perisphinctid from 750 ft.

WITHERS, T. H. 1926. *Catalogue of the Machaeridia* (*Turrilepas and its Allies*). Brit. Mus. (Nat. Hist.)

WOOLDRIDGE, S. W. 1923. The Minor Structures of the London Basin. *Proc. Geol. Assoc.*, vol. xxxiv, p. 175.

—— 1926. The Structural Evolution of the London Basin. *Proc. Geol. Assoc.*, vol. xxxvii, p. 162.

Chapter III

WEALDEN AND LOWER GREENSAND

WEALDEN

NO WEALDEN BEDS have been proved in the present area. They are, however, present in considerable thickness immediately southward, and it is inferred that they underlie the Lower Greensand in the southern part of the district, and thin rapidly northward to zero, since they do not appear in the borehole at Nashenden nor indeed in any borehole in the area which proves strata below the Lower Greensand.

LOWER GREENSAND

A small outcrop of the topmost division of the Lower Greensand, the Folkestone Beds, occupies a limited tract S.W. of Snodland, below which Sandgate Beds and Hythe Beds have been proved in boreholes. Northward of the Snodland district, however, the Lower Greensand persists only as a thin bed which on present data cannot be subdivided.

ATHERFIELD CLAY. The presence of Atherfield Clay beneath the Hythe Beds of the Snodland district is inferred, since this formation occurs over an unbroken outcrop along the northern edge of the Weald of Kent and Surrey, and is recorded from boreholes at New Hythe and Aylesford, immediately south of the area under description. If present its thickness is probably not more than 20 ft.

HYTHE BEDS. At Snodland Paper Mills a borehole (272/79a) proved 115 ft of Hythe Beds, probably reaching nearly to the base. It can only be conjectured what beds may represent the Hythe Beds in the deep Lower Greensand boreholes of the northern and eastern part of the district. Changes from a rock and sand facies to one dominantly clayey, particularly in the lower part, become marked even a short distance northwards from the outcrop of these beds immediately southward of the district. In the record of the borehole at Snodland (272/79a) 20 ft of dark sands and clays with layers of rock are underlain by 95 ft of blue and brown clay (probably partly sandy with thin beds of hard grey rock. The Kentish Rag type of limestone rock of the outcrop thus persists, but the normal intervening beds of soft sandy 'hassock' are largely replaced by clays. Further north at depth the rock layers disappear and the Hythe Beds either thin out to zero or have hitherto been unrecognized.

SANDGATE BEDS. These beds normally consist of dark sandy clays with much glauconite, and reach a maximum thickness of some 20 ft beneath the Snodland area, but probably thin out to zero on the north and east. Some lithological types as recorded from the deep boreholes to the Lower Greensand suggest Sandgate Beds but no proof of their actual position within the Lower Greensand is forthcoming (cf. Kirkaldy 1937, p. 115). At Snodland Paper Mills 16 ft of Sandgate Beds are indicated in one borehole section (272/79a) while at Holborough Cement Works a borehole (272/128) penetrated Sandgate Beds to a depth of about 10 ft. At New Hythe just south of Sheet 272, borehole records show a variation in thickness of these beds from 6½ ft to over 20 ft.

FOLKESTONE BEDS. The Folkestone Beds in Snodland Paper Mills borehole are 171½ ft thick, and half a mile to the north, at Holborough Cement Works (272/128), they thin to 125 ft. At Halling and Wouldham, a number of boreholes have entered undoubted Folkestone Beds, but further north and east, lithological types comparable with Folkestone Beds have been recorded only in one or two instances.

At their outcrop S.W. of Snodland the Folkestone Beds consist of fine or medium-grained white and buff current-bedded sands with occasional clayey partings and a little loam, ironstone and ferruginous sandstone. At the top, coarse glauconitic shelly chert in thin beds and lenses is found locally, and provides a convenient datum to mark the top of the formation. The transition to the overlying Gault is usually through variable sandy and clayey passage beds. Unweathered sand from boreholes is frequently green; where hard beds are recorded at the top, they may represent chert beds. The lower part of the Folkestone Beds as proved in boreholes consists largely of very fine grey sand, at some sites somewhat silty or loamy, at others sharp and clean.

DETAILS

A lane-cutting at Parson's Corner, over half a mile west of Austen's Farm, near Snodland, and just over the border of Sheet 272 (Dewey and Bromehead 1924, pp. 8, 9), exposed the following beds, representative of those of the present area, below the basal beds of the Gault:

	Ft
Base of Gault (see p. 25)	4
Coarse firm sand, brown and shelly	1
Very hard coarse glauconitic shelly chert bed, rather irregular in development	1–2
Brown and blue-green coarse cherty sandstone or firm brown sand ..	2–3
Highly glauconitic, blue, green and purple loam and sandy clay, with impersistent beds and lenticles (½–3 in thick) of pale buff chert ..	3
Rather coarse current-bedded sand with shelly chert beds a few inches thick and a firm clay-silt band about a foot down	4
Highly glauconitic firm sand and sandstone with thin ironstone bands and an impersistent clayey band at the top; strong current-bedding with foresets to the south-west	5

Between 300 yd and 400 yd east by north of Parson's Corner, but within Sheet 272, strongly-developed chert beds were again visible in the sands beneath the Gault capping the road-banks. Coarse brown glauconitic loam and sand with cherty beds and shell fragments were also seen 200 yd east of the Vicarage, and the road-bank on the north side of Austen's Farm showed a few feet of orange sand with coarse brown pebbly sandstone and clayey seams near the top.

West, north and east of Horn Street are white, yellow, orange and brown sand and sandrock, lower down in the Folkestone Beds than the cherty strata. About 250 yd S.E. of Horn Street 25 ft of ironstained sand, mostly fine and with seams of pipe clay, were seen in an old pit. Some 300 yd E.N.E. of the Inn at Ham Hill the northern of two small pits in sandy gravels showed 2 ft of sand and bedded ironstone at the base, and a small pit 200 yd E. of the Inn showed 6 ft of current-bedded sand.

Sections north-west of the Inn at Ham Hill exposed beneath variable drifts (*see* p. 125) the lowest part of the Folkestone Beds to be seen at outcrop in the area. The best section seen was that in the most westerly pit, which showed

15 ft of mainly fine white sand with current-bedding not very well marked but diversified with brown and grey streaky seams up to several feet thick and lying parallel or at varying angles, and with thin ferruginous soft sandstone towards the top in places, overlying 6 ft of dominantly brown and greyish rather loamy sand with seams of pure white sand.

In the most northerly pit the sand, exposed to a depth of 15 ft was mainly fine and white, current-bedded and with brown and buff streaks of firm sand, up to 2 ft thick, containing aggregations of large ironstained sand grains. Similar sands, though not always current-bedded, with loamy patches towards the bottom and sometimes with thin anastomosing clay partings were also exposed near the entrance to this pit. A series of trial-holes approximately at the site of these workings proved beneath overlying drift, white, yellow and brown sands down to a depth of 70 ft. White sand is dominant but brown sand forms the base; records of 'small flints' in the lowest beds most probably refer to pebbly sands or broken up ironstone and sandstone. The record of one borehole (No. 4 of the driller's records) shows some variation in the nature of the sand as follows:

	Ft
Drift	5
Fine red sand	2½
Yellow sand	5
White sand	2½
Light brown sand	1
Dark brown sand	12
Light brown sand	2½
White sand	18
Fine brown sand	5
Total	53½

Three trial-holes in the alluvial tract south of Snodland, the exact sites of which are not known, proved Folkestone Beds beneath the Drift respectively as follows: 8 ft of sand overlying 1½ ft of very hard sand rock; light yellow sand 10 ft; and light yellow sand 19½ ft.

LOWER GREENSAND UNDER THICK COVER

At Nashenden Pumping Station borehole (272/104b), 3½ miles N.E. of the outcrop, the Lower Greensand has thinned to 77 ft in all; at Frindsbury Cement Works (272/32c) it is 83 ft and at Cliffe Marshes (272/23b), 96 ft; E.N.E. of a line through Cliffe and Frindsbury, and which probably continues on the west side of Luton before curving more easterly, a further reduction of thickness is apparent. At Chatham Dockyard (272/6b) and at Gillingham Gasworks (272/100a) the formation is only 42 ft thick; at Luton Pumping Station (272/9a) the Lower Greensand was not proved to be bottomed at 41 ft, the borehole stopping in clay which probably belongs to clayey beds towards the base of the formation. At Rainham Waterworks, 1¾ miles to the east, the deeper of two boreholes (272/61b) stopped in loamy beds extending from 42 ft to 50 ft down in the formation. Eastwards again and to the north the general thickness of about 40 ft seems to hold, the boreholes at Bobbing (272/24) and at Sheerness East Waterworks (272/90) passing through 36 ft and 44 ft respectively.

The character of the beds met with in these borings is summarized below.

(1) *Nashenden Pumping Station, 2 miles S.W. of Chatham* (272/104b).

Description of the top 31 ft is from the well-sinkers' record, the rest from specimens in the Geological Survey collections:

	Ft
Hard clay (sandy), with hard sand and loamy sand in the bottom 11 ft	31
Grey compacted rather coarse sand with shelly fragments, becoming coarser, more clayey, pebbly and greenish downwards	20
Coarse dark green clayey sand	2
Fine grey micaceous sandy clay, becoming coarser and pebbly downwards	13½
Dark grey clay, somewhat sandy	1
Coarse pebbly sand with large quartz grains, lydite pebbles; lumps of pyritous quartzite, hard sandstone and black lignite; a little dark clay, etc.	9½
Total	77

The lowest bed contains materials probably derived from the Palaeozoic. The beds as a whole are not referable lithologically to the normal Lower Greensand subdivisions which appear to have lost their identity in the condensed sequence.

(2) *Capstone Pumping Station, 2 miles S.E. of Chatham* (272/10b).

A borehole here entered the Lower Greensand at a depth of 622 ft and continued in it for 43 ft. The beds are described in the well-sinkers' record as green sand 9 ft, followed by hard green sand 34 ft. A 2-in bed of 'gault rock' may be referable to the top of the Lower Greensand rather than to the Gault.

(3) *Luton Pumping Station, 1½ miles S.E. of Chatham* (272/9a).

Whitaker (1908, p. 103) described 6 ft of light-coloured sand followed by 11½ ft of dead green sand with clay. Finch (1929, p. 6) records the beds below these, making a total of 41 ft. Clean sand, dark at the top and bottom but white and with two thin rock beds in the middle, is underlain by clay at the base; it is possible that further boring would encounter clayey beds (cf. Nashenden) to the base of the formation. The separation by Whitaker of the top 17½ ft into Folkestone and Sandgate Beds, cannot be justified in relation to the total 41 ft described by Finch in which Hythe Beds are not recognizable.

(4) *Rainham Waterworks, Rainham Mark* (272/61).

At this site two boreholes entered the Lower Greensand.
The first proved the following:

	Ft
Hard rock (Sandstone)	3
Soft loamy greensand	3½
Very hard rock	1½
'Lower Greensand'	20
Total	28

The second borehole went deeper into the Lower Greensand, probably nearing its base. Again two rock-beds are recorded at the top of the formation, a feature noticeable in further sections and possibly representing the chert beds of the outcrop at Parson's Corner, etc. The relative absence of clay content is to be noted again:

	Ft
Rock	5
Sand	3
Rock	1½
Green sand	32½
Black loamy sand	8
Total	50

(5) *Dove, Phillips and Pett Limited (formerly Budden and Biggs Brewery), High Street, Strood* (272/124b).

Sandrock, 3 in and grey sand, 5 ft 8 in, over white sand, 16 ft 7 in, suggest sands of the Folkestone Beds type.

(6) *British Oil and Cake Mills Limited, Canal Road, Strood* (272/82).

Whitaker recorded 14 ft 10 in of 'fine sharp greenish-grey sand', to which a 2-in rock bed at the top, placed by him with the Gault, should probably be added.

(7) *Rochester Gasworks* (272/101b).

The deepest borehole here passed through 20 ft 6 in of sand. One version of the record notes 'rock nodules' immediately below the Gault, possibly again representing the chert beds.

(8) *Frindsbury Cement Works* (272/32c).

The well-sinkers' original record describes the Lower Greensand beds as follows:

	Ft
Sand rock	4
Green sand	9
Sandstone and rock	5
Sand and gault	29
Sand and rock	36
Total	83

This differs somewhat from Whitaker's account (1908, pp. 142, 383) which makes no reference to 'gault' (i.e. clay) or to rock in the lower part, except for a basal 2 ft of sandstone. The occurrence of rock at the top is to be noticed again and the description of the beds as a whole gives an impression of a condensed sequence preserving the Folkestone-Sandgate-Hythe subdivisions.

(9) *Whitehall Cement Works, Frindsbury* (272/33).

2 ft 6 in of rock and 5 ft of sand were proved; the rock was previously grouped with the Gault but is now included in the Lower Greensand.

(10) *Chatham Dockyard* (272/6b).

The detailed descriptions and discussion by Whitaker (1908, p. 100) and by Lamplugh (1923, p. 161) of the 42 ft of Lower Greensand proved in this deep boring differ considerably. Lamplugh places 1 ft of hard calcareous rock at the top of the formation and not with the Gault, which accords with present views. He notes that such a rock-band occurs in many other borings. Both accounts recognize Folkestone Beds and Sandgate Beds, but differ in the relative thicknesses assigned; both regard the Hythe Beds and Atherfield Clay as being absent. A re-examination of the specimens has shown, however, that lithologically they do not compare with the normal appearance of the Folkestone Beds and Sandgate Beds at the outcrop; most are impure sands, and sandy clay comes from the bottom 11 ft.

(11) *Gillingham Gasworks* (272/100a).

This borehole penetrated 42 ft of Lower Greensand, described as stony in the top 11 ft with the 31 ft below consisting of black sandy clay with the clay content increasing downwards. An alternative version places a 2-ft seam of green sand a few feet down in the black sandy clay. Dewey (*in* Dewey and others 1925, p. 134) mentions 17 ft of Lower Greensand resting on Oxford Clay but it seems more probable that only the bottom 4 ft of the strata bored belong to the Oxford Clay.

(12) *Chattenden Barracks, north of Upnor* (272/31).

About 4 ft of Lower Greensand were entered, apparently greenish sand. The record, however, is imperfect (Whitaker 1908, p. 140). 'Rock' 9 in thick recorded at the base of the Gault may represent the hard beds noted elsewhere at the top of the Lower Greensand, or may be phosphatic nodules.

(13) *Cliffe Marshes* (272/23b).

A thickness of about 96 ft of Lower Greensand was proved, but the only recorded details are in notes by Whitaker (1908, pp. 109 and 382), who described a specimen of 'brownish-grey sand, not like the ordinary sand of the formation, with pieces of chert'. He expressed doubts about the true thickness but examination of the whole series of records of local boreholes encountering Lower Greensand shows the above to be reasonable. Lamplugh (1923. p. 185) followed by Kirkaldy (1933, p. 300), placed the bottom 10 ft of Whitaker's Gault with the Lower Greensand. While the presence of chert or other rock-beds at the top of the Greensand might have been expected, a thickness of 7½ ft of 'gault with stones and fossils' seems better placed with the base of the Gault, and Whitaker's classification is here regarded as the more probable.

(14) *Bobbing, trial-boring for coal* (272/24).

36 ft of beds comprising hard glauconitic calcareous grit near the top, sand in the upper part, and clay in the lower, are grouped by Lamplugh (1923, p. 153) as Folkestone Beds and Sandgate Beds.

(15) *Sheerness East Waterworks* (272/90).

According to Lamplugh (1923, p. 184) 44 ft of Lower Greensand were passed through, but the record is unsatisfactory, and Lamplugh suggested that his thickness may be an over-estimate. Both coarse sand and fine glauconite sand are represented, with white sand of 'Folkestone Bed type' at the base. Some rock or sandstone seems to be present at the top.

S.C.A.H.

REFERENCES

DEWEY, H. and C. E. N. BROMEHEAD. 1924. Geology of the Country around Dartford. *Mem. Geol. Surv.*

DEWEY, H., J. PRINGLE and C. P. CHATWIN. 1925. Some recent Deep Borings in the London Basin. *Sum. Prog. Geol. Surv.* for 1924, p. 127.

FINCH, W. C. 1929. A Remarkable Artesian Boring. *Selected Engineering Papers No. 70, Inst. Civil Engineers.*

KIRKALDY, J. F. 1933. The Sandgate Beds of the Western Weald. *Proc. Geol. Assoc.*, vol. xliv, p. 270.

—— 1937. The overstep of the Sandgate Beds in the Eastern Weald. *Quart. Journ. Geol. Soc.*, vol. xciii, p. 94.

LAMPLUGH, G. W., F. L. KITCHIN and J. PRINGLE. 1923. The Concealed Mesozoic Rocks in Kent. *Mem. Geol. Surv.*

Chapter IV

GAULT

THE CLAY formation of the Gault is about 235 ft thick in the vicinity of the outcrop which occupies but a small tract in the south-western corner of the area. This figure is indicated by three boreholes respectively at Holborough Cement Works (272/128), at the former Wouldham Hall Cement Works (272/88b) and at the former Burham (West Kent) Cement Works (272/4). The Gault is 220 ft to 225 ft thick at Halling Waterworks (272/47), northward of which, as also in the southern half of the area generally, the thickness ranges from about 170 ft to about 205 ft, while in the north-east, at Sheerness East Waterworks (272/90), it has diminished to 134 ft. The basal bed, a sandy clay, on borehole evidence averages about 5 ft but is apparently some 10 ft thick at Cliffe Marshes (272/236). At the outcrop only about 2 ft of this sandy clay were seen.

The top quarter or so of the Gault consists of blue-grey slightly micaceous marl or marly clay, becoming tougher downwards. It may be slightly sandy, especially at the extreme top. Below this the main mass is a blue-grey stiff clay with glauconite, mica and sand generally only appearing again towards the base, where the clay also becomes darker and scattered phosphatic nodules and occasional pyrite or marcasite lumps may occur sporadically. The basal bed is a green, highly glauconitic, sandy clay with beds of phosphatic nodules; sometimes the green sand dominates the clay content. The base may be taken for convenience above the chert bands which, as noted in Chapter III, are frequently developed at the top of the Folkestone Beds, although both in a palaeontological and in a lithological sense it is difficult to define the base with precision. The borehole (272/236) at Cliffe Marshes passed through 2½ ft of 'conglomerate and hard rock', which appears to be abnormal but which may represent a bed of closely-packed phosphatic nodules. The variation of the chemical composition of the Gault reflects its passage upwards into the Lower Chalk, which the top part closely resembles when weathered. In the clay pits, three-quarters of a mile south by west of Burham formerly extensively worked for cement and brick-making, the 'top white clay' showed 38·72 per cent $CaCO_3$, while the 'middle clay' of the pit showed 29·00 per cent $CaCO_3$. At the bottom the amount of calcium carbonate was shown on analysis (in MS.) to be 22·36 per cent and this clay, stratigraphically about 75 ft down in the Gault, has the following composition:

	%
Silica (SiO_2)	38·95
Alumina (Al_2O_3)	17·50
Ferric oxide (Fe_2O_3)	6·20
Lime (CaO)	15·52
Magnesia (MgO)	1·43
Carbon dioxide (CO_2), water (H_2O) and organic matter	18·40
Alkalies and loss	not determined
Total	98·00

In the present area the Upper Greensand facies is absent, the Lower Chalk resting directly on the Gault.

DETAILS

The base of the Gault is to be seen at Parson's Corner over half a mile west of Austen's Farm near Snodland and a little west of the western boundary of the present area.

The section is as follows:

	Ft
Blue clay weathering pale grey	2
Stiff dark coloured blue and green sandy clay, highly glauconitic and containing phosphatic nodules	1
Very highly glauconitic sandy clay with many phosphatic nodules (associated with large sand grains) and fossiliferous; green and blue colour modified by much rusty weathering	1
Folkestone Beds	

This section was briefly described by C. E. N. Bromehead (*in* Dewey and Bromehead 1924, p. 9) who listed fossils which prove the presence of the Dentatus and Mammillatum zones but other fossils occur throughout the sequence which passes into the Folkestone Beds below and the precise position of the base of the Gault is doubtful. In the lane-cutting 350 yd west of Austen's Farm blue Gault overlies highly glauconitic Gault with phosphatic nodules. On tracing the base of the Gault for some half a mile further east, glauconitic clay with phosphatic nodules was noticed in a number of places, notably in the road bank 50 yd S.W. of Christ Church, at the southern end of Snodland. Hereabouts sandy phosphatic nodules occur in wash on the falling ground below the outcrop. Beyond this point the base of the Gault is hidden beneath the Medway alluvium.

In 1938 a pit about 550 yd E.S.E. of Paddlesworth showed at one point on the north the base of the Lower Chalk with the Chloritic Marl (*see* p. 30) but elsewhere the section was entirely in Gault, with local small pockets of drift, to a depth of some 30 ft. All round the pit the top 10 ft of clay showed calcareous concretions known as 'race' in white streaks, patches and small nodules. Weathered dull grey or brownish and rather hard but flaky, the clay when fresh is dark blue and homogeneous, except for occasional shell-fragments. Immediately to the east the Upper Gault was formerly exposed in a large pit, now overgrown.

The southern end of the Associated Portland Cement Company's Holborough Chalk quarry, just N.W. of Snodland, exposes the Gault. In 1938 about 30 ft of clay were to be seen below the horizon of the Chloritic Marl. At the top the clay is glauconitic and in places for some 12 ft contains white streaks, and patches of race. Passing downwards the clay soon loses its glauconite, is pale and fissile on weathering and has much the appearance of the marls near the bottom of the Lower Chalk except that large weathered lumps retain bluish cores. The bottom 15 ft showed relatively fresh dark blue-grey clay with conchoidal fracture. The clay from the most recent excavation showed on analysis approximately 35 per cent to 40 per cent of calcium carbonate.

Around Snodland and again on the east side of the Medway the Gault outcrop is mainly covered by drift. About three-quarters of a mile south by west of Burham, however, there is less drift, and the clay was formerly dug extensively; in 1938 it was still being dug in the upper part of the Burham pit, where the section was observed to be approximately as follows:

	Ft
Brown-weathered clay, with embedded white flints, etc.	1
Light greyish firm clay with white patches and streaks of race	10
Firm, heavy, dark clay, blue when fresh but weathering into lumps partly fissile and partly conchoidal-fracturing; a further stage of weathering breaks this down into friable and often creamy-coloured fissile material	35

The analysis of clay quoted above is of material from this section. Topley (1875, pp. 147, 148) mentioned the pit and in a footnote referred to two trial borings proving Gault to 160 ft and 200 ft. Jukes-Browne (1900, p. 89) gave details of the section (then 90 ft to 100 ft) as seen by W. Hill in 1896. He noted an abrupt change, some 35 ft down, from light-coloured clay to darker, and very glauconitic clay was seen at the base of the section. A list of fossils from the lower 10 ft of the worked face apparently represents the lowest fossiliferous horizon, except for the basal bed of the Gault, recorded within the present area. Spath (*in* Dibley 1922, p. 75 and Dibley and Spath 1926, p. 433) has given more recent descriptions of the clay and its fossil horizons (Upper Gault) in this pit, noting also light grey clay with race immediately beneath the Chloritic Marl (*see* p. 33) in the tramway cutting some 600 yd east by north of the pit.

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PALAEONTOLOGY

The Gault displays no palaeontological features of special interest in this area. In the Lower Gault only the Dentatus-Spathi and Monile Subzones have been identified, but the Upper Gault is well represented. The following zones and subzones are known to occur:

	Zone	Subzone	Equivalent beds at Folkestone
Upper Gault	Dispar	Substuderi	XIII
	Inflatum	Aequatorialis	XI-XII
		Auritus	XI
		Varicosum	X
		Orbignyi	IX
Lower Gault	Lautus	Cristatum	VIII
	Dentatus	Dentatus-Spathi	I
	Mammillatum	Monile	Ia

Beds of pre-Dentatus Zone age are known only at Parson's Corner, in the extreme S.W. corner of the area. Here a bed of phosphatic nodules exposed in a road-cutting yielded ammonites of the Mammillatum Zone (Monile Subzone) (Dewey and Bromehead 1924, p. 9), but the base of the Gault, in both the lithological and palaeontological senses, is ill-defined. There is a series of glauconitic loamy sands with concretionary spicular bands and scattered phosphatic nodules passing into sandy Folkestone Beds with cherty stone-bands below and into blue Gault Clay above. For convenience, the top of the Folkestone Beds is taken at the highest well-marked stone-band (*see* p. 18).

Above the Dentatus-Spathi Subzone with *Protanisoceras? flexuosum*, the remainder of the Lower Gault appears to be wanting at Burham, for faunas of the Intermedius and Niobe Subzones of the Dentatus Zone and the Subdelaruei, Lautus-Nitidus and Daviesi Subzones of the Lautus Zone are not represented in the collections (*see also* Spath 1943, p. 738). This gap represents the upper part of Bed I and Beds II to VII inclusive, or about 18 ft of beds at Folkestone, while at Dunton Green to the west of the present area, some 22 ft of Dentatus Zone clays are succeeded by a nodule-bed 4 in thick in which the whole of the Lautus Zone is represented (Wright *in* Wright and Thomas, 1946).

LIST OF FOSSILS

The only exposure in the area from which fossils are listed here is the lowermost of the great series of pits on the south face of Bluebell Hill, but this pit is now flooded and much overgrown, so that only the unfossiliferous topmost beds can be seen. The fossils found here by Geological Survey officers are listed below (with revision of the species recorded by Jukes-Browne 1900, p. 89) and lists follow of the ammonoids and cirripedes specifically mentioned from this area by Dr. L. F. Spath and Mr. T. H. Withers respectively.

Foraminifera
    Epistomina caracolla (Roemer)

Annelida
    Serpula antiquata J. de C. Sowerby

Crinoidea
    Isocrinus fittoni (Austin)

Brachiopoda
    Kingena lima (Defrance)

Lamellibranchia
    Acila (Truncacila) bivirgata (J. de C. Sowerby)
    Anomia cf. *laevigata* J. de C. Sowerby
    Aucellina gryphaeoides (J. de C. Sowerby)
    Barbatia marullensis? (d'Orbigny)
    Cardita tenuicosta (J. de C. Sowerby)
    Corbula truncata J. de C. Sowerby
    Cyprina quadrata d'Orbigny
    Entolium orbiculare (J. Sowerby)
    Grammatodon carinatus (J. Sowerby)
    Inoceramus concentricus Parkinson
    Isognomon raulinianus (d'Orbigny)
    Nucula ovata Mantell
    N. (Pectinucula) pectinata J. Sowerby
    Nuculana vibrayeana (d'Orbigny)
    Ostrea vesicularis Lamarck
    Oxytoma pectinatum (J. de C. Sowerby)

Gastropoda
    Anchura (Perissoptera) marginata (J. de C. Sowerby)
    '*Aporrhais*' cf. *bicarinatoides* Wollemann
    Gyrodes genti (J. Sowerby)
    Solarium conoideum J. de C. Sowerby

Cephalopoda
- *Neohibolites listeri* (Mantell)
- *Beudanticeras beudanti* (Brongniart)
- *Epihoplites gibbosus* Spath (Spath 1923–43 (1926), vol. i, p. 186, footnote)
- *Euhoplites sp.*
- *Hysteroceras binum* (J. Sowerby)
- *H. orbignyi* Spath
- *H. varicosum* (J. de C. Sowerby)
- *Idiohamites spp. juv.*
- *Lechites sp.*
- *Mortoniceras* (*Pervinquieria*) aff. *rostratum* (J. Sowerby)
- *Neokentroceras ? sp.*
- *Prohysteroceras* (*Goodhallites*) cf. *goodhalli* (J. Sowerby)
- *Scaphites sp.*
- *Turrilites plicatus* d'Orbigny

B. Additional ammonoids specifically recorded by Spath (1923–43)
- *Anahoplites planus* (Mantell)
- *Dimorphoplites parkinsoni* Spath
- *Epihoplites compressus* (Parona and Bonarelli)
- *E. denarius* (J. de C. Sowerby)
- *Euhoplites alphalautus* Spath
- *Hysteroceras carinatum* Spath
- *Idiohamites tuberculatus* (J. Sowerby)
- *Lepthoplites falcoides* Spath
- *Mortoniceras* (*Pervinquieria*) *rostratum* (J. de C. Sowerby)
- *M.* (*P.*) *sp. juv. indet.* (pl. xxxix, fig. 4a)
- *Protanisoceras ? flexuosum* (d'Orbigny)
- *P. ? sp. nov. ? indet.* (pl. lxvi, fig. 9 and text fig. 205q, p. 575)
- *Scaphites simplex* Jukes-Browne (pl. lvii, fig. 13)
- *S. subcircularis* Spath

C. Cirripedes specifically recorded by Withers (1935)
- *Cretiscalpellum unguis* (J. de C. Sowerby)
- *Pycnolepas rigida* (J. de C. Sowerby)
- *Scalpellum* (*Arcoscalpellum*) *gaultinum* Withers (pl. xxv, fig. 1)

R.V.M.

REFERENCES

DEWEY, H. and C. E. N. BROMEHEAD. 1924. The Geology of the Country around Dartford. *Mem. Geol. Surv.*

DIBLEY, G. E. 1922. Excursion to Blue Bell Hill, Rochester. *Proc. Geol. Assoc.*, vol. xxxiii, p. 75.

DIBLEY, G. E. and L. F. SPATH. 1926. Report of an Excursion to Burham and Aylesford, Kent. *Proc. Geol. Assoc.*, vol. xxxvii, p. 432.

JUKES-BROWNE, A. J. 1900. The Cretaceous Rocks of Britain, vol. i, The Gault and Upper Greensand. *Mem. Geol. Surv.*

SPATH, L. F. 1923–43. A Monograph of the Ammonoidea of the Gault. 2 vols. *Palaeont. Soc.*

TOPLEY, W. 1875. The Geology of the Weald. *Mem. Geol. Surv.*

WITHERS, T. H. 1935. *Catalogue of Fossil Cirripedia in the Department of Geology, vol. ii, Cretaceous.* Brit. Mus. (Nat. Hist.).

WRIGHT, C. W. and H. DIGHTON THOMAS. 1946. Notes on the Geology of the country round Sevenoaks, Kent. *Proc. Geol. Assoc.*, vol. lvii, p. 315.

Chapter V

CHALK

THE THREE main subdivisions of the Chalk—Lower, Middle and Upper—are all well represented in the Chatham area. The total thickness of the formation averages about 700 ft, variations from this being due probably to local changes in thickness of the Middle but especially of the Lower Chalk. The maximum thickness is on the south, towards the escarpment, where, including an estimate for Upper Chalk removed by denudation, the total calculated thickness is about 750 ft. From borehole records at Chatham Dockyard (272/6), Frindsbury (272/32c), Strood (272/82), Cliffe Marshes (272/23b) and Bobbing (272/24), the Chalk is proved or calculated to have a total thickness of about 680 ft to 700 ft. At Sheerness (272/90), it reaches the minimum recorded, 668 ft, which may indicate a general thinning down dip. At the outcrop the Chalk is readily separable into its main subdivisions, but this is frequently difficult to effect on the evidence of records of dug wells and of boreholes. The Melbourn Rock, at the base of the Middle Chalk, and the Plenus Marls just below it are the most easily recognizable horizons in these records but rarely can the base of the Upper Chalk be determined with any degree of accuracy unless good samples or cores carrying fossils are available.

Apart from the small area at Cliffe and East Tilbury the Chalk outcrop is confined roughly to the southern half of the district, with its upper boundary trending east-south-eastward, and the strike bringing Tertiary beds progressively nearer the southern border. Only in the Medway valley does Lower Chalk come to crop and Middle Chalk also is seen only here and in the tributary valleys near Cuxton, although it is probably close to the surface in Chatham on account of minor folding (p. 8).

Literature on the Chalk of the Chatham district is extensive especially regarding the large sections in the Medway valley. Specific references to these many earlier descriptions have been omitted here, except where special points have arisen or where descriptions have been amplified from previous accounts. A list of works additional to those referred to in the following text is given on p. 53.

Recent palaeontological evidence has resulted in the correction of certain errors in earlier zonal interpretations of some sections and has added more precision to others.

For a general account of the Chalk, the two memoirs of Jukes-Browne may be consulted; these memoirs also include accounts of the Chalk of Kent and an extensive bibliography covering the history of research. A palaeontological summary is included in the Geological Survey memoir dealing with the adjacent Dartford area (Dewey and Bromehead 1924). Of the earlier accounts the more important are those of Whitaker (1872), Hood (1884) and Dibley (1900, *et seq.*).

LOWER CHALK

Usually about 200 ft thick in this area, the Lower Chalk varies nevertheless within the limits of about 175 ft to 235 ft, according to well-records, but is less commonly below than above 200 ft.

The formation is divisible into the fossil zones given in downward sequence below with a summary of the characteristic lithological types:

Subzone of *Actinocamax plenus:*

Normally greenish yellow marl and marly chalk with lenses of hard chalk interbedded; locally a bed of hard marly chalk with a thin marl band at the top, and sometimes another at the base. Constantly present but with thickness variable up to 10 ft from place to place.

Zone of *Holaster subglobosus:*

Blocky chalk, white at the top but becoming greyer downwards and passing without distinct lithological break into the beds below. Mainly compact but with occasional thin marly partings .. .. About 80–100 ft

Zone of *Schloenbachia varians:*

Chalk becoming more marly and fissile than above, though much remains compact and uniform. Hard beds developed towards the base. General dark grey appearance when fresh, white when weathered. Glauconite, quartz sand and mica towards base, scattered at first but increasing downwards to form the Chloritic Marl below. Dark clayey lenses may be present just above the latter bed .. .. 100 ft or more

The Chloritic Marl.

Highly glauconitic marl with phosphatic nodules—a constant basal bed of the Chalk. Where thin it is often difficult to detect .. .. .. 2 in to 2 ft

The term 'Chalk Marl' is not included in the above summary as its usage conforms but vaguely with the sequence as observed in this district, where no sharp lithological change occurs in the lower part of the Lower Chalk.

Analyses (in MS.) of samples from the Lower Chalk at Burham show a downward increase in silica and alumina and a decrease in lime, a characteristic feature of this formation generally:

	'Grey chalk' %	'Marl' %
Moisture	17·30	8·46
Silica	3·52	14·56
Alumina	1·22	5·30
Ferric oxide	0·30	1·00
Lime	51·71	41·93
Magnesia	0·43	0·60
Sulphuric anhydride	Trace	0·09
Loss on ignition	41·18	34·60
Alkalies undetermined	1·64	1·92

At the Holborough Quarry (*see* p. 31) the Lower Chalk has been sampled in detail to determine the relative percentages of calcium carbonate, in connexion with cement manufacture. The highest figure is about 92 per cent for the higher beds of the Lower Chalk; the average is about 80 per cent; and the lowest figure is 60 per cent, or perhaps less, in the variable clayey and calcareous beds immediately above the Chloritic Marl.

DETAILS

Beds of the Varians Zone, together with the Chloritic Marl, were seen above the Gault in the north-west part of the clay-pit 550 yd E.S.E. of Paddlesworth, in the S.W. corner of the district, where the following section was recorded:

Grey chalk marl, rubbly and weathered at the top	about 2 ft
Intensely hard nodular fossiliferous bed	„ 6 in
Soft to firm marl, weathering white	„ 1 ft
Intensely hard massive fossiliferous bed	„ 6 in
Soft to firm marl, weathering white and with a fossiliferous horizon at the base	„ 4 ft
Highly glauconitic marl with well-developed black phosphatic nodules; the upper limit indistinct but the base sharply defined	„ 1 ft

The Lower Chalk is well exposed N.W. of Snodland; a small exposure, 50 yd east of the Tumulus E.N.E. of Holborough Hill and above the large Holborough Quarry, showed about 12 ft of massive chalk with small nodules about 50 ft down in the Subglobosus Zone. This lithology, unusual for the Lower Chalk, is reminiscent of the Melbourn Rock.

The Holborough Quarry continues the section downwards through the Varians Zone and reaches the Gault. The quarry, which has been much extended westward in recent years, showed in 1939 the following generalized section:

	Ft
Blocky chalk	100
Dark marl with hard beds and clayey lenses; glauconite increasing downwards	14
Chloritic Marl (highly glauconitic and phosphatic)	1

The blocky chalk weathers white but in the lowest 40 ft is very dark grey when freshly dug. Nodules of pyrite are common, but fossils are scarce except in the lower half. The dark marl with stone and clay, striking in appearance, shows considerable lateral variation. The marl is fissile or friable and slightly micaceous and where very clayey resembles the Gault, except that it is more fissile. The included stony beds consist of hard chalk, some in intensely hard fossiliferous courses 6 in to 1 ft thick. The Chloritic Marl has occasional fossils and abundant phosphatic nodules varying in colour from white to brown, green and black. It is somewhat clayey in places and is typically green or greenish brown from the concentration of glauconite.

In the Halling and Upper Halling districts the ground is mostly occupied by extensive quarries in the Lower Chalk, the majority long since disused, in which the junction with the Middle Chalk, and the Plenus Marls overlying the top beds of the Subglobosus Zone, are clearly seen. A generalized section of the beds beneath the Melbourn Rock or 'Burr' is given below:

	Ft
Plenus Marls ('soap' of the quarrymen). Greenish yellow marl with intercalated hard chalk bands and lenses, very variable but consistently present	2–10
Chalk of the Subglobosus Zone (Grey Chalk). Dull white and greyish, firm to hard, blocky chalk, strongly but irregularly jointed; occasionally fissile marly bands; pyrite nodules and fossil fish teeth common	60–80

400 yd N.N.E. of Lad's Farm, a ditch in the base of the pit exposed a few feet of chalk of the Varians Zone as recorded by Dewey (1924, p. 38).

On the east side of the Medway, the Lower Chalk is again almost continuously exposed from Wouldham to Burham in huge disused quarries. In the Schoolfarm Lime Works pit, half a mile S.E. of Wouldham Church, 1 ft of yellow fissile marl passing down into 3 ft of firm marly and blocky chalk with irregular marly levels enclosing lenses of hard blocky chalk, the whole grouped as Plenus Marls, was seen overlying 40 ft to 50 ft of blocky greyish chalk of the Subglobosus Zone. The quarry east of Wouldham Hall exposes Lower Chalk from the Plenus Subzone, through the whole of the Subglobosus Zone down to the Varians Zone. This representative section shows the variability of the Plenus Marls:

		Ft
Plenus Marls	Yellow marl with intercalated seams and lenses of hard white but not nodular chalk	1½–3
	Gradual passage to firm greyish white marly chalk, the base in places with a thin marly seam	4–5
	Massive firm to hard, conchoidal-fracturing and blocky white and dull white chalk, with pyrite nodules; in general becoming greyer downwards and more marly, though some beds are very hard	80–100
	Gradual passage down into variably fissile grey marly chalk with pyrite, passing in turn into soft grey fissile but firm marl over half way down	25

Immediately north-west of Burham a further large disused pit exposes similar beds, but the top is inaccessible. About 80 ft of blocky chalk overlie without sharp division some 25 ft of variable marly chalk with both pale and dark compact beds. Below the Melbourn Rock in a small disused chalk working 180 yd east of the church at Burham village, beds of the Plenus Marls were seen to divide into two 6-in seams separated by 1 ft of firm blocky white chalk; below the lower seam of marl come 15 ft to 20 ft of blocky, greyish-weathering, soft chalk.

The great series of quarries about three-quarters of a mile south-east of Burham expose a continuous sequence from the Upper Chalk at Bluebell Hill (*see* p. 42) through Middle Chalk and Lower Chalk down to the Gault. Parts of these quarries were in work during 1938 but the sections in the Upper and Middle Chalk and some in the Lower Chalk have been abandoned for many years. The section described below the Melbourn Rock in the disused parts one-third of a mile N.E. of Great Culand is as follows:

	Ft
Yellowish grey laminated marl with variable bands and lenticles of hard white rather lumpy chalk	1–1½
Paler yellowish grey marly chalk weathering conspicuously, with distinct yellow colour	6–8
Firm blocky chalk with pyrite nodules; some thin marly partings; white at the top, becoming greyer downwards	80–90
Somewhat darker marly chalk with pyrite, not clearly demarcated from the above	15–20

The top two beds are grouped as Plenus Marls. Most of the chalk below is in the Subglobosus Zone, but at the base of the quarry the Varians Zone is represented. This zone also appears to have been exposed at one time in the cuttings and tunnel extending south-west from this pit, passing on the north side of Great Culand and Little Culand. West of Great Culand about 60 ft of greyish buff, variably marly chalk weather white and contain a number of hard bands; while eastward, where in 1938 the Lower Chalk was being worked east of Great Culand to a depth of 90 ft, the top 40 ft were whiter in appearance than that below, though the lower, more marly and fissile, beds also showed up white when weathered. Largely in the Varians Zone, the beds nevertheless include the lower part of the Subglobosus Zone. In the cutting from this pit leading west past Little Culand about 30 ft of blocky to marly chalk showed a weathered face of soft marly wash. Farther west at the junction with the Gault, about 2 ft of glauconitic marl with phosphatic nodules overlie the grey clay of the Gault which was proved 250 yd W. of Little Culand.

Northward of the outcrop the Plenus Marls and the Chloritic Marl are on occasions recognizable from well-sinkers' descriptions of deep wells and boreholes, and from the fragmentary specimens produced by percussion methods of drilling. At Chatham Dockyard (272/6b) 16 ft of hard greenish chalk probably include the Plenus Marls, while at Capstone Waterworks (272/10) 9 ft of the Marls are recorded. A well in Friends Wood, two-thirds of a mile S. of Lidsing, however, only indicated a 6-in soapy layer at the horizon of the Plenus Marls (272/109). Sometimes recorded as 'Upper Greensand', the Chloritic Marl appears in the records of a number of wells in the Chatham and Rochester district, ranging in thickness from 2 in to 2 ft. A thickness of 6 ft of 'Upper Greensand' recorded from Strood (272/82) probably includes chalk marl with a little sand and glauconite passing down into the Chloritic Marl, similar to that at Frindsbury Cement Works (272/32c) where 2 ft of 'grey chalk and sand' overlie 1 ft of 'Upper green sand'. At Luton Waterworks (272/9a) the Chloritic Marl is 2 ft or more thick and contains mica and probably phosphatic nodules, while 2 ft of greenish sand are recorded at this horizon at Sheerness East Waterworks (272/90).

MIDDLE CHALK

The thickness of the Middle Chalk is a little over 200 ft, the measured section of 207 ft at Burham being representative. It is but 182 ft in the borehole at Rochester Gas Works (272/101) and probably not more than 180 ft beneath the Luton Valley, where drift irregularly covers the valley floor and probably fills channels in the Middle Chalk. At Snodhurst Waterworks (272/95) 217 ft of Middle Chalk were proved. A maximum thickness of about 230 ft is calculated from sections and the outcrops on the scarp between Burham and Wouldham; 229 ft are recorded in the well in Friends Wood noted above.

The lower boundary of the Middle Chalk, at the base of the Melbourn Rock, is usually well marked but the upper is normally only determined after considering variation in lithology in conjunction with palaeontological criteria (*see* pp. 38–9).

The lithology of the two palaeontological zones of the Middle Chalk is summarized as follows:

	Ft
Zone of *Terebratulina lata* (up to 140 ft):	
Soft to semi-nodular chalk, sometimes with a rough texture, with hard spongiferous lumps and courses of very hard yellow-hearted nodules; flints, mainly nodular, are concentrated in bands or are irregularly dispersed; marl seams are frequently developed ..	about 30
Massively-bedded clean white chalk, soft and homogeneous (apart from nodular beds noted below) and with well-developed marl seams; at the top the chalk is occasionally lumpy and thin brown-stained nodular courses are common, but occasionally well-developed intensely hard spongiferous beds also occur through a thickness of 50 ft from the top of the zone and a bed of small nodules has been recorded over 60 ft down; scattered flints, locally numerous, occur in the top half, and small nodular flints and thin tabular flint sometimes occur down to some 70 ft; at the base a gradation into the less homogeneous chalk of the zone below ..	up to 110

Zone of *Inoceramus labiatus* (also known as the Zone of *Rhynchonella cuvieri*) (up to 90 ft):

	Ft
Irregularly-jointed white chalk with thin marly partings; though passing up insensibly into the chalk above, it is mostly rather rougher and becomes gradually harder and more lumpy downwards	up to 45
Brittle white chalk, fracturing to lumps, with impersistent thin marl seams; small kernels of nodular chalk are liable to develop throughout this chalk, grading into the Melbourn Rock below	20–30
Melbourn Rock: Hard yellowish nodular chalk, with many small hard creamy kernels set in lumpy whiter chalk with irregular thin marly partings; the bottom part may be more intensely hard and massive than above	6–15

The Middle Chalk has only the relatively thin marl seams diversifying it, so that in chemical composition it is uniformly pure and high in $CaCO_3$ compared with much of the Lower Chalk. Analysis of the 'Burr' (the quarryman's name for Melbourn Rock) at Burham showed an average of about 92 per cent of calcium carbonate, i.e. about the same as for the top beds of the Lower Chalk below the Plenus Marls.

DETAILS

On the west side of the Medway, north-west of Snodland and towards Upper Halling, the lower boundary of the formation is well marked by the Melbourn Rock, which caps Holborough Hill, it shows in the bare chalk soil north of Paddlesworth, and is seen above the Plenus Marls of the Lower Chalk on the much-quarried ground west of Halling. About one-third of a mile W.S.W. of Upper Halling Church quarrying operations have extended old workings in the Lower Chalk and Melbourn Rock upwards in the Labiatus and Lata zones of the Middle Chalk. In the upper pit and a narrower cutting connecting with the lower beds on the east the section to be seen in 1938 was:

	Ft
White chalk, massive and blocky apart from occasional brown spongiferous chalk nodules, with small nodular flints only in the top 20 ft; occasional thin marly partings in bottom 50 ft; irregular jointing	80–90
Brittle white chalk, fracturing to lumps, with some small kernels of nodular chalk developing in the lower part	20–30
Melbourn Rock; hard yellowish chalk kernels or nodules set in white lumpy chalk, with irregular thin marly partings	10–15

The top of the Middle Chalk—soft blocky chalk with very hard nodules in the upper part—was seen in the steep lane half a mile west-north-west of Upper Halling Church. The old quarry immediately to the east of Upper Halling showed Melbourn Rock consisting of a 6-ft top layer of moderately hard chalk enclosing small hard kernels resting on 6 ft of very hard rock streaked irregularly with thin marly partings. Here the overlying chalk is brittle and only slightly lumpy but in the pits two-thirds of a mile N.W. of Upper Halling Church the Melbourn Rock showed a less definite upper limit, the chalk being still nodular though not so intensely hard, 25 ft above the Plenus Marls.

Nearly 170 ft of Middle Chalk (Lata and Labiatus zones) were noted beneath the Upper Chalk (*see* p. 39) in a large disused pit ('White Pit') half a mile north by east of Upper Halling. The section is typical of the Middle Chalk, showing the development of rougher chalk in the Labiatus Zone and of hard courses above the soft blocky chalk nearing the top:

	Ft
Chalk with hard spongiferous lumps; many nodular flints, especially towards the base	5–8
Soft lumpy chalk with some harder courses and not many flints; brown lumps present especially near base	20
Conspicuous marl seam (2–4 in)	
Blocky white chalk, with nodular flints and occasional brown lumps towards the top	60
Conspicuous marl seam (2–4 in)	
Massive but soft blocky white chalk	30
Marl seam (2–4 in)	
Chalk as above	10
Thin marl seam	
Blocky chalk becoming less homogeneous towards the base	20
Rather brittle and irregularly splitting rougher white chalk with many fragments of *Inoceramus* (beds seen only in an excavation in the floor of the quarry)	20

A mile to the N.E., the large disused quarry by Whorns Place, Cuxton, exposes about 136 ft of similar beds beneath those classed as Upper Chalk (*see* p. 40).

Middle Chalk occupies the Cuxton Valley and the tributary valleys entering it on the south. It is here largely covered by Drift, but near Cuxton, a temporary excavation 250 yd N.W. of the church exposed blocky clean white chalk with few nodular flints and, lower down in the sequence, brittle and lumpy chalk was exposed 100 yd E.S.E. of the White Hart Inn. The disused quarry in Upper Chalk 750 yd N.E. of Cuxton Station (*see* p. 40) is apparently floored by Middle Chalk, though it could have been formerly exposed only to about 4 ft. East of Cuxton the Middle Chalk outcrop passes underneath the Medway.

An old chalk pit half a mile W.S.W. of Borstal and E. of the river (the 'Borstal Manor Pit' owned by Booth & Co., cited by Dibley 1899–1900, p. 488, and by Jukes-Browne 1904, p. 160), exposed about 35 ft of the Lata Zone beneath Upper Chalk as follows:

	Ft
Chalk mainly without flints	11
Massive rather lumpy chalk, with a 1-ft brown spongiferous nodular course 1 ft 6 in from the base	6
Conspicuous marl seam	
Massively bedded chalk with hard spongiferous lumpy courses, a few flints	10
Firm rather blocky chalk with few flints; common *Spondylus*	10

Dibley later (1912, p. 372; 1918, p. 3) used the name 'Borstal Manor Quarry' for another pit (p. 41).

A disused pit half a mile N.N.E. of Wouldham Church exposes about 80 ft of chalk of the Lata and Labiatus zones, without reaching the top of the former or the bottom of the latter. The chalk is softer and more homogeneous at the top than below. A marl seam is conspicuous 20 ft down, followed by thin irregular marly partings beneath it. In the Schoolfarm Lime Works pit (*see* p. 31), half a mile S.E. of Wouldham Church, the base of the Middle Chalk was seen as follows:

	Ft
Lumpy nodular white chalk, with an impersistent marl seam about 5 ft down	10
Nodular chalk passing down gradually into very hard massive yellowish Melbourn Rock (about 5 ft) with small nodular kernels and, near the base, oblique marly partings	12

Similar beds, with well-developed Melbourn Rock, cap the Lower Chalk (*see* p. 32) in the huge disused quarries east of Wouldham Hall and just north-west of Burham, but in many places the quarry faces are inaccessible.

Above the Wouldham quarries and about half a mile N.E. by E. of Wouldham Hall the middle and lower parts of the Lata Zone were well seen in a pit at and below the 300-ft contour line, as follows:

	Ft
Very lumpy and irregularly weathered hard nodular chalk with brown stains, softer chalk in the middle, with a band of nodular flints	12
Conspicuous marl seam (4 in)	
Soft chalk with some brown lumps; many scattered nodular flints in the upper half	4
Intensely hard nodular bed, weathering very lumpy; brown and yellowish staining and many fossil sponges; base rather indistinct	4
Soft to moderately hard chalk with nodular flints becoming small and scarce towards the base	15
Soft blocky chalk without flints, except occasional very thin tabular flint and tiny nodular flints near the top, where also the chalk may be slightly lumpy; massively bedded, apart from thin marly partings about	30

This section is of special interest in that it shows the development of hard beds and the presence of flints about 100 ft down in the Middle Chalk; and also, when considered in conjunction with other local exposures, that the Lata Zone is hereabouts some 140 ft thick, leaving about 90 ft for the Labiatus Zone and that the Middle Chalk is here at its maximum thickness of 230 ft. About half a mile S.S.E., chalk of about the same horizon, carried a little higher on the escarpment because of the dip, was exposed in a small overgrown pit behind Scarborough Terrace, a quarter-mile N.N.W. of the church at Burham village. About 20 ft of mainly blocky chalk contain occasional harder patches and a few nodular flints.

The top of the Middle Chalk was seen beneath the Upper Chalk in the lane-cutting section (*see* p. 42) high on the scarp face about 700 yd north of the church at Burham village; fossil sponges and *Inoceramus* are common in 10 ft to 15 ft of rough-textured and lumpy chalk with a few small nodular flints. Similarly, 350 yd south-west of the Robin Hood and Little John, at about 440 ft O.D. in the path ascending the scarp from Burham, some 20 ft of soft lumpy chalk with hard yellow nodular bands and flints underlie the Upper Chalk (*see* p. 42).

In the small disused chalk working 180 yd E. of the church at Burham village 9 ft of hard nodular Melbourn Rock, white to yellowish and with many small hard kernels of chalk, were seen above the Plenus Marls. In the road cuttings 200 yd north-east of the church and 300 yd north-north-west of the church the Melbourn Rock passes gradually upwards into fairly hard massive and brittle chalk, but the small hard kernels do not die out till about 20 ft above it.

A complete section of the Middle Chalk, totalling 207 ft in thickness is afforded by the two highest quarries, disused for many years, a third of a mile

W. of Bluebell Hill. Between the Upper Chalk (*see* p. 42) and the Lower Chalk (*see* p. 32) in this series of quarries the measured section is:

	Ft
Rather soft mealy and lumpy chalk	3
Lumpy chalk with many scattered nodular flints	3
Variably lumpy white chalk	8
Hard brown-stained spongiferous nodular chalk with a thin marl seam in the middle; in some places this type extends up into part of the bed above, in others it is itself partly replaced by softer chalk	about 12
Massively-bedded but mainly soft white chalk with a few flints	20
Band of hard spongiferous brown-stained nodules	1
Massively-bedded soft to firm white chalk, with several very thin impersistent marly seams but only rare flints at the top	60
Marl seam	
Soft to firm white chalk	20
Marl seam	
Soft to firm white chalk, massively-bedded and with some harder levels	40
White chalk becoming gradually harder and more lumpy downwards, developing small nodular kernels and grading into the bed below; *Inoceramus* common	30
Hard nodular Melbourn Rock, with many small kernels and creamy patches; hardest at the base; '*Rhynchonella cuvieri*', *Inoceramus labiatus*	10

Melbourn Rock was seen about 250 yd W.S.W. of the Lower Bell Inn, about 1½ miles S.E. of Burham, where it overlies the Plenus Marl in the road bank and is there shifted several feet by a small fault.

Immediately N. and N.E. of the Lower Bell Inn some 93 ft of Middle Chalk (Lata Zone) were noted beneath the Upper Chalk (*see* p. 42) in five large disused chalk pits. Some, but not all, of the beds vary considerably in detail in each pit, but the section 350 yd north by west of the Lower Bell may be taken as typical:

	Ft
Lumpy chalk with hard brown nodules, very hard and spongiferous mainly in the lowest 3 ft; nodular flints, impersistent, near the top	9
Indistinct marl seam, disappearing to the south and there replaced by a flint band	
Soft chalk	1½
Band of nodular flints, with crowded fragments of *Inoceramus* shells just above	
Lumpy chalk with some brown nodules	8
Thin marl seam (up to 2 in)	
Soft chalk	1
Band of nodular flints	
Lumpy chalk with intensely hard brown spongiferous nodules concentrated in the middle 3 ft	9
Marl seam (4–6 in)	
Soft blocky chalk, with flints and slightly lumpy chalk at the top	30–40

Spondylus is common in the nodular beds and *Holaster planus* is found well below the base of the Upper Chalk. The other sections, all distanced from the Lower Bell Inn are: 500 yd N. by W. with 72 ft of similar beds; 250 yd N. with 93 ft of similar beds and at the base, a 4 in grey marly seam resting on a 4 in band of greyish chalk with small hard brown nodules; 450 yd N.E. with 15 ft of chalk of the Lata Zone; and 500 yd N.E. by E. with 54 ft of chalk of the Lata Zone with lumpy nodular beds and flints more or less throughout.

In the area south of Warren Farm to the border of the district the soft to lumpy chalk with hard spongiferous nodules is traceable on hillslopes and in lane-banks, etc.

Underground the hard beds of the Labiatus Zone grading down into the Melbourn Rock are commonly recognizable from borehole records; while it is not usually possible to set an upper limit to the Melbourn Rock with accuracy, the base may usually be distinguished. The well in Friends Wood (272/109, *see* p. 33) records 23 ft of very hard chalk overlying 6 ft of similar chalk of a darker colour which probably represents the Melbourn Rock.

UPPER CHALK

Calculations from borehole evidence and from outcrops show that the Upper Chalk, where present in full, averages about 300 ft in thickness, with but little variation over the whole area. In borehole records it is rarely possible to separate the Upper from the Middle Chalk with any degree of accuracy but combined thicknesses of the two and totals for the Chalk as a whole support this general estimate. Moreover, fossil collecting from beds near the Tertiary outcrop has provided no evidence of the presence of the Uintacrinus or Marsupites zones, and indicates that probably the top 40 ft or so of the Coranguinum Zone are absent beneath the Thanet Beds. The absence of these higher beds contrasts with conditions in the Dartford area to the west where as a result of pre-Tertiary folding, the Uintacrinus and Marsupites zones are present in a number of places, and similarly to the east where a succession of higher zones above Coranguinum appears in the Isle of Thanet region.

The lithology and zonal divisions of the Upper Chalk are tabulated below. In this formation certain broad lithological types serve as rough guides to horizon but lateral variation is often considerable (*see*, for example, p. 48) and the basis of subdivision is primarily palaeontological. Only at the base of the Upper Chalk does a constant lithological sequence hold over the whole area. But to determine this horizon in the field, fossil collecting is a necessary guide, to avoid confusion with similar beds both above and below (the latter in the Middle Chalk). The fauna of this basal bed includes gastropods and other shallow-water fossils and is named the *Reussianum* Fauna from the occasional presence of the ammonite *Hyphantoceras reussianum*. It may, however, also be found at higher horizons although usually without the eponymous ammonite. These later occurrences can be dated by the characters of the associated forms of *Micraster*. In the Middle Chalk below, only *M. corbovis* and rare *M. leskei* occur, both with smooth areas which remain so upwards into the Upper Chalk only in the case of *M. leskei*. The following zonal summary records a number of hard rock-beds, some of which are more persistent than those hard beds which occur in the Planus and Cortestudinarium zones.

	Ft
Zone of *Micraster coranguinum*:	
Mainly soft featureless chalk with flint bands varying from about 4 ft to about 10 ft apart, scattered flints being subordinate; marly seams practically absent; occasional yellowish lumpy chalk at the top but otherwise courses of harder chalk only found locally in the bottom half; the basal beds usually clean white brittle chalk with tabular and nodular flint or blocky chalk becoming rougher and more lumpy downwards (distinct hard nodular beds practically absent); in the lower half but mostly a little above the base of the zone much broken *Inoceramus* but few other fossils. Estimated thickness	160

	Ft
Zone of *Micraster cortestudinarium:*	
Very variable chalk with scattered flints and flints in bands often only 2 ft or 3 ft apart, but not always strongly developed; marl seams rare; hard 'chalk-rock' beds common (thin seams in places numbering eight or more) and of two types—seams of yellowish compact or nodular rock, with fossil sponges and commonly pyritous (usually 6 in to 1 ft thick), and massive rocky beds, less well-defined, composed of hard nodules variably concentrated in a matrix of soft, mealy or rough chalk (up to 10 ft thick); lateral variation general, but a compact smooth limestone or a more nodular rock-bed marks the top of the zone in a number of places and at, or somewhat above the base, hard beds 2 ft to 3 ft thick may occur; Polyzoa are common in the zone and *Echinocorys* tends to occur crowded in thin bands. Estimated average thickness	80
Zone of *Holaster planus* (up to 70 ft):	
Variable chalk with many flints, scattered and in bands; marl seams occur especially in the lower part; hard spongiferous yellowish nodular 'chalk-rock' interbedded with or occurring as more isolated nodules in rough but softer lumpy chalk; three or more hard beds additional to the basal bed (*see below*), usually thin or vaguely defined but locally a 6-ft bed at the top (or thinner rocky bed near the top) and a persistent bed (1 ft to 1 ft 6 in) over 15 ft above the base containing fossils of the Reussianum Fauna, while at the top large *Echinocorys* is frequent	about 55

Characteristics of the basal beds are:	Ft
Band of large flints	
Mainly soft lumpy chalk, sometimes partly nodular	3–5
Marl seam (1–3 in)	
Rough chalk with intensely hard yellowish, semi-crystalline nodules with Reussianum Fauna especially concentrated about 2 ft down or lower; nodular flints in the middle, usually an indistinct band	4–6
Band of large flints	

In discussing the chemical composition of the Upper Chalk generally Jukes-Browne (1904, p. 354) states that apart from some variation in the rough and rocky beds the chalk is 'a remarkably pure calcareous deposit varying very little in composition, and almost always containing from 97½ per cent to 99 per cent of calcium carbonate', an estimate true of the present area.

DETAILS

Planus Zone: West of the River Medway chalk of this zone fringes the main valley and those dry-valley branches extending W. and S.W. of Cuxton. In numerous places intensely hard yellowish nodules of 'chalk-rock' type containing sponges, casts of gastropods and other fossils are to be seen at the surface or in lane-banks and other minor exposures and they are interbedded with rough but softer lumpy chalk with many flints.

The large disused quarry (White Pit) half a mile N. by E. of Upper Halling showed the following sections of Planus Zone chalk above the Middle Chalk (*see* p. 34):

	Ft
Chalk with nodular flints; top part inaccessible, the base soft and lumpy with harder brown nodular seams	20–30
Brown nodular bed with lamellibranch casts	1
Moderately lumpy chalk with flints	6–7
Conspicuous band of large flints	
Mainly soft lumpy chalk	5
Marl seam (1–2 in)	
Rough soft and lumpy chalk with very hard nodules irregularly distributed but concentrated about 2 ft down; an indistinct band of nodular flints in the middle. The 'chalk-rock' nodules are yellowish and fibrous or semi-crystalline; they contain gastropod casts and other fossils of the Reussianum Fauna	5
Conspicuous band of large flints	

In the banks of the track-cutting 550 yd N.E. of this quarry and about 250 ft O.D. some 20 ft of lumpy chalk with hard crystalline nodules yielded *Micraster* indicative of low Planus Zone. At a higher level similar chalk, with large *Echinocorys*, was seen in the banks of the track some 50 yd further north; a conspicuous hard rocky bed may mark the top of this zone.

The large disused 'Bores Hole' quarry by Whorns Place, Cuxton, shows about 110 ft of Upper Chalk above the Middle Chalk. Most of the Upper Chalk is inaccessible, so that it is not possible to define the exact junction of the Cortestudinarium and Planus zones. The basal Planus beds agree closely with those at the White Pit and contain Reussianum fossils in a 3-ft bed with its base 6 ft below the marl seam. In the lane-cutting 50 yd W. of Cuxton Church about 16 ft of flinty chalk, with a nodular bed containing sponges and casts of gastropods, etc. are referred to the lower part of the Planus Zone.

About 100 yd N.E. of Dean Farm a small chalk pit exposed about 10 ft of soft chalk with large nodular flints and a band of brown nodular chalk near the base. *Echinocorys* is common. This section may include some chalk of the overlying zone.

The bottom of a disused quarry 750 yd N.E. of Cuxton Station just cuts the Middle Chalk. The basal beds of the Planus Zone agree in detail with their development in the Whorns Place section and were seen at the S.E. end of the cutting leading into the pit as follows:

	Ft
Band of large flints	
Weathered chalk	1
Marl seam (impersistent at Whorns Place)	
Weathered lumpy chalk	1
Band of large flints	
Lumpy chalk	3
Marl seam	
Lumpy chalk with hard brown and yellow fibrous nodules with sponges and Reussianum fossils	2+

The main section, which according to Jukes-Browne (1904, pp. 160, 161) includes both Planus and Cortestudinarium zones, is now interpreted to be all of the Planus Zone apart from 4 ft of Middle Chalk at the base. About half a mile farther N.E. chalk is excavated at the large Wickham Cement Works (also known as Martin Earle's Pit). The Planus Zone is touched at the bottom but its base there dips below the level of the Medway alluvium. The following section, noted at the S.W. end of the nearby disused quarry between the two railway lines, demonstrates the presence—a frequent occurrence—of the Reussianum or 'chalk rock' type of fauna considerably above the base of the zone, a fact corroborated by the *Micraster* fauna below the 1 ft 6 in nodular band:

	Ft
Rather lumpy chalk	20
Hard yellow nodular band with casts of gastropods and lamellibranchs, etc.	1½
Rough soft and lumpy chalk with occasional harder nodules; *Micraster praecursor* of low Planus Zone type	15

Jukes-Browne's description (1904, p. 161) covers 77 ft 6 in of chalk which he placed in the Cortestudinarium and Coranguinum zones but which in point of fact are mainly referable to the Planus Zone, extending into the zone above *Micraster cortestudinarium* was found about 10 ft from the top. The band of yellow crystalline chalk described 30 ft from the top is probably a little way down in the Planus Zone.

On the E. side of the Medway valley the Planus Zone is well exposed from Borstal southwards, rising gradually to cap the Chalk escarpment. The dry valleys of the dip-slope do not, however, cut down to the Middle Chalk (except possibly beneath the Luton valley drifts) and the lowest Planus beds are not seen there.

At Borstal a deep disused chalk pit 100 yd N. of the church ('Borstal Manor Quarry' of Dibley 1912, p. 372 and 1918, p. 73), with a section of nearly 60 ft of Planus Zone chalk below that of the Cortestudinarium Zone (*see* p. 46), almost reaches the base of the zone but exposes a rock bed with gastropods, etc., which must be at least 15 ft above the zonal base; the bed is comparable with that recorded above, on the other side of the Medway, at Wickham Cement Works. The Planus chalk of the Borstal section is as follows:

	Ft
Soft to lumpy chalk with bands of nodular flint; large *Echinocorys* noted	14
Lumpy ironstained course	2½
Softer chalk	1½
Seam of tabular flint, dividing into two in places and replaced by nodular flint on the east	
Mainly soft chalk	4½
Thin seam of tabular flint with another about 1 ft above it in places	
Chalk of variable hardness, with large nodular flints and very hard brown lumpy courses, indistinct except for a 1-ft bed at the base ..	12
Soft and lumpy chalk	9
Soft chalk with nodular flints	2
Rough chalk with casts of fossils	1
Hard brown-stained nodular bed, with fossil sponges, gastropod casts, etc., in a soft rough matrix	1
Rough chalk, largely soft, with hard cores in places and casts of fossils; distinct flint band about 2 ft down	12

About 50 ft of similar beds were seen in the old pit, connected to the preceding by a tunnel, 300 yd N.W. of the church but the two 1-ft fossiliferous nodular beds bracketed above are here less distinct and have become flinty. The *Micraster* fauna in the lowest beds indicates low Planus Zone and the basal Reussianum bed probably lies a few feet below the floor of both pits. An old chalk pit half a mile W.S.W. of Borstal showed 35 ft of Planus beds above the Middle Chalk (*see* p. 35). Here again the base of the zone is marked by flinty nodular chalk with hard courses containing Reussianum fossils down to about 6 ft below a well-defined marl seam, itself separated by about 5 ft from a conspicuous band of large flints above it.

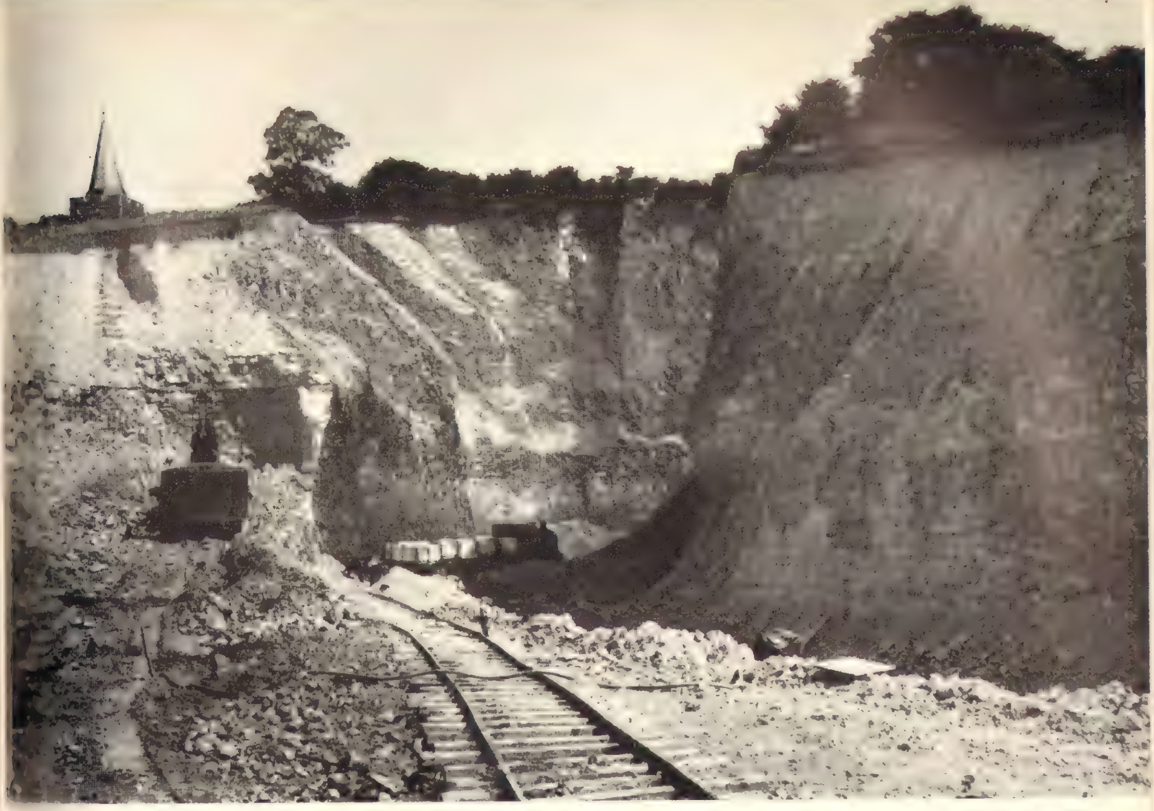
Southwards, rising steadily on the hillside past Wouldham, nodular and rough lumpy chalk of the Planus Zone and the hard rocky sponge-bearing nodules about its base can be traced sporadically where the chalk is bare or cut by hillside lanes and tracks. An overgrown pit 200 yd S. of Ringshill Place yielded Planus Zone fossils, *Micraster* and *Echinocorys* being common. In the road bank 100 yd N.N.E. of this, at a somewhat higher level, massive lumpy chalk with sponges was seen alternating with softer courses. About half-a-mile W.N.W. of Burham Hill sporadic exposures were seen in the lane descending the hill across Wouldham Common. For about 60 ft the chalk is rough, soft or lumpy, with flints and bands of hard spongiferous nodules, but at the base there are intensely hard yellow nodules, with the Reussianum Fauna, cropping out a little below the 400-ft contour line. In the lane-cutting high on the scarp face about 700 yd N. of the church at Burham village, a weathered and partly obscured section showed about 63 ft of Planus Zone chalk overlying the Middle Chalk (p. 36) and succeeded by chalk of the Cortestudinarium Zone (p. 49); hard nodular bands and cores of hard chalk were noted at various levels but Reussianum gastropods, together with *Inoceramus* of various species, seem to be common only at the base, which is here at about 415 ft O.D. Again, 340 yd S.W. of the Robin Hood and Little John Inn, in the path ascending the escarpment from Burham, about 15 ft of Planus Zone chalk with fossiliferous Reussianum nodules in the bottom 4 ft (about 460 ft O.D.) were seen.

About a quarter of a mile W. of Bluebell Hill the top 40 ft of chalk in the uppermost of the series of huge disused quarries exposes the characteristic lithological sequence at the base of the zone. Zonal thicknesses differ from those of Jukes-Browne (1904, p. 159), the present revised section being as follows:

	Ft
Chalk with indistinct bands of nodular flint (inaccessible)	15
Similar chalk, rough and lumpy, with *Holaster planus* common	10
Marl seam (2 in)	
Soft chalk	1
Conspicuous band of nodular flint	
Massive course of hard nodular chalk	4
Soft chalk	1
Marl seam (2–3 in)	
Lumpy chalk with intensely hard yellow-hearted nodules mainly concentrated in a 2-ft band about 1 ft down (Reussianum gastropods, etc.) and to a less degree in the lowest 1 ft; an indistinct band of nodular flint in the middle	5
Band of large nodular-tabular flints	

Upper Chalk of the Planus Zone caps five disused pits in Middle Chalk (p. 37) N. and N.E. of the Lower Bell Inn about 1½ miles S.E. of Burham. A pit 350 yd N. by W. of this inn showed the following:

	Ft
Chalk (inaccessible) with a band of nodular flints in the middle	7
Nodular flint band	
Rather lumpy chalk	3½
Marl seam (2–3 in)	
Intensely hard brown and yellow nodular chalk, partly crystalline, with gastropod casts, etc. (Reussianum Fauna)	2
Nodular flint band	
Lumpy chalk becoming to a large extent replaced southwards with hard nodules as in the bed above	2
Nodular flint band becoming semi-tabular southwards	



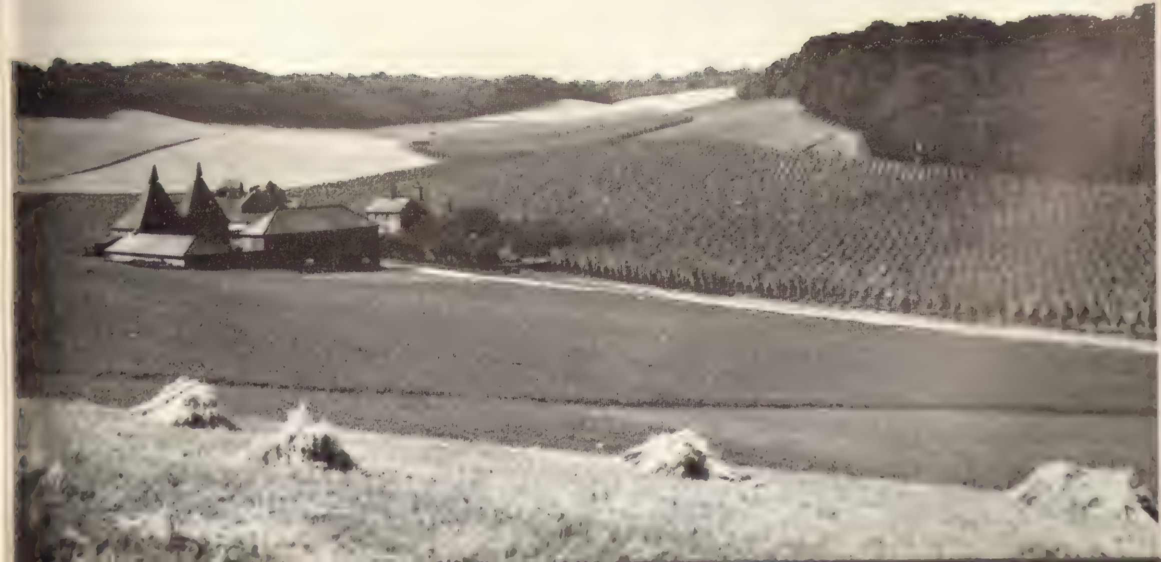
(A 7864)

A. QUARRY IN UPPER CHALK, FRINDSBURY

PLATE II

B. DRY CHALK VALLEY, DEAN FARM, CUXTON

(A 7893)



A pit 500 yd N. by W. of the inn extends the section upwards another 20 ft in flinty chalk which is not accessible; one 250 yd N. of the inn only exposes 5 ft or 6 ft of chalk higher than the basal Reussianum horizon with its characteristic marl seam a foot or two above. The same marl seam and Reussianum bed were seen at the base of some 25 ft of Planus Zone chalk in the degraded quarry 450 yd N.E. of the inn, while in the adjacent quarry 500 yd N.E. by E. of it the basal bed is less thick, as follows:

	Ft
Lumpy chalk, partly soft, with flints	10
Marl seam (2 in)	
Soft lumpy chalk passing down into the bed below	1½
Hard nodular band with gastropods, etc., of the Reussianum Fauna, up to	1
Band of large nodular and semi-tabular flints	

About 400 yd N.N.E. of this inn part of the top beds of the Planus Zone, consisting of 5 ft of hard lumpy and nodular chalk with flints and common *Echinocorys* were seen to rest on 18 ft of flinty but less nodular chalk with a fossiliferous horizon about 6 ft down. The top of the zone appears to be about 8 ft above this section.

When traced round the indented escarpment to the eastern edge of the present area the base of the Planus Zone is seen gradually to rise until the 500-ft contour line is touched. In the banks of the track descending the scarp from Westfield Wood past this point poorly exposed lumpy chalk includes, at about the 500-ft level, hard yellowish nodules with sponges and fragments of other fossils.

It is calculated that this chalk must form the floor of the valley system southwards of Nashenden Farm and chalk of this zone crops out in the valleys which are separated from the preceding by the high ground over which run the several roads connecting Maidstone with Rochester and Chatham. In the Snodhurst valley on the southern outskirts of Chatham a small pit on the east side, near 'Victoria Road' and about 750 yd S.E. of Bridgewood Gates, exposed 2 ft of lumpy chalk with *Holaster planus* beneath probable Cortestudinarium chalk (p. 47). The top of the zone is here somewhat higher in position than the normal dip would bring it; there is evidence for a gentle strike flexure which also markedly affects the Cortestudinarium chalk near Walderslade Bottom (*see* p. 47). At Snodhurst the top of the zone lies about 20 ft below the valley floor, as calculated from the evidence of neighbouring sections and a well-record at Snodhurst Pumping Station (272/95). In the Walderslade valley two exposures in flinty lumpy chalk of the Planus Zone were seen in shallow irregular workings on the east side of Tunbury Wood, one near the road and about three-quarters of a mile S.E. of Walderslade Bottom and the other 200 yd to the W.N.W. The bottom 15 ft of flinty chalk with a rather indefinite rocky bed, exposed in a disused chalk pit 70 yd S.E. of the road-junction at Walderslade Bottom (*see* p. 47) are referred to the Planus Zone, which is clearly indicated by a distinctive *Micraster* series. About a quarter of a mile N.N.W. the valley turns N.E. The Planus Zone falls below the valley floor on the north-north-east side of the local transverse flexure. Within half a mile of Upper Luton, however, the zone most probably again comes to the surface, for in the harder and rougher lower part of the chalk sporadically exposed in the road-cutting at East Hill, just south of Upper Luton, the *Micraster* fauna of this zone was identified. Further, near the Technical Institute, at the south-eastern end of Chatham High Street (just west of the railway bridge) specimens of *Micraster leskei* of low Planus Zone type collected by W. Gamble prove the zone to have risen there in a like manner. This rise is brought about by the Luton valley strike fold, and the Planus Zone floors the valley through Luton north-westwards into Chatham for about 1¼ miles beyond its junction with the Walderslade valley. In the deepest part of this valley, indeed, about Hale, Upper Luton and even on the S.E. side of Chatham, the Planus chalk may be cut out by Drift irregularly reaching the Middle Chalk. South-eastwards the Planus Zone is estimated to floor the valley until higher beds succeed at Speeks Bottom. Near the commencement of the Capstone valley an old chalk pit 100 yd E.N.E. of the Pumping Station exposed about 25 ft of rough chalk with rather indistinct thin hard bands averaging 4 or 5 ft apart and bands of nodular flints; a 2-in seam of grey marl occurs about the middle of the section. The beds dip S.S.W. about 3°, in response to the Luton Valley anticline. Fossils are scarce but sufficient to identify the Planus Zone. Just south of this the zone falls below the valley floor, for at Capstone Pumping Station (272/10) the well section indicates the presence of nearly 60 ft of Upper Chalk. The Planus Zone evidently remains beneath the level of the Capstone valley and its western branch throughout the whole length of their rise to the dip-slope.

In the separate valley system S.E. of Bredhurst and near the southern edge of the area it is not likely that Planus chalk appears in the valley bottoms but it may do so in the deep valley south of Matt's Hill for a stretch of about a mile above the Pumping Station (272/106). A well (272/109) in Friends Wood, two-thirds of a mile south of Lidsing, reached the base of the Upper Chalk at about 134 ft. Five beds of hard chalk were encountered, of which four are referred to the Planus Zone. It is thought that the valley here has not quite cut down to Planus chalk. The Planus Zone, however, was identified in the western branch of this valley south of Cockhill, at a point almost on the border of the present area. Here, 500 yd S. by E. of Lower Cox Street, an old pit low on the east side of the valley showed the following section:

	Ft
Nodular rock-chalk in places intensely hard and smooth-fracturing ..	6
Mainly soft chalk with few flints	6
Band of nodular and tabular flint	
Mainly soft chalk with bands of large flints; some indistinct bands of harder chalk	12

Echinocorys is common and the *Micraster* fauna determines the horizon, including the nodular rock, as the top of the Planus Zone. The presence of the Planus Zone at this point probably indicates gentle folding.

Cortestudinarium Zone: On the W. side of the River Medway, chalk of this zone appears about three-quarters of a mile S. of the Cuxton valley, where the northerly dip accounts for its presence capping the high ground. West of North Halling it occurs in the high face of the old 'Bores Hole' quarry (*see* p. 40) and was found in two degraded pits on the steep valley side just south-west of this. The more southerly of these, about 170 yd W.N.W. of the footpath reaching the Pilgrims' Way from North Halling, showed a small section of soft and lumpy chalk, with flints and hard yellowish nodular courses, amounting to about 28 ft, with more of the pit obscured. *Micraster cortestudinarium* and *Micraster praecursor* found here have the features characteristic of the zone, but in the small pit 250 yd N. by W. of the footpath from North Halling only *Echinocorys* was found in about 30 ft of similar chalk with hard nodular beds and many flints. In the 'Bores Hole' quarry (p. 40), it is estimated that 40 ft or more of Cortestudinarian chalk cap the section which is inaccessible and specimens of *Micraster* recorded show the appropriate zonal characters. It is possible that Cortestudinarium chalk may be present in the small pit about 100 yd N.E. of Dean Farm.

On the northern side of the Cuxton valley, the lower slopes of the valley sides, including the ground cut through by the railway, are formed of massively-bedded flinty chalk of this zone. An old pit 200 yd N. by W. of Court Lodge exposed about 12 ft of lumpy chalk with nodular flints and very hard yellowish courses, especially one at the base and another 6 ft up. The fauna indicates the base of the zone. North-east of Cuxton, the Rochester road and the railway near it most probably cut through chalk of this zone as far as Wickham Cement Works, west of Temple Marsh. The large sections excavated here extend from near river-level to over 150 ft O.D., passing from the Planus Zone (*see* p. 40) through the Cortestudinarium Zone, the highest working probably cutting Coranguinum chalk. Northward of this point the dip carries the beds below the ground surface but on the left (north-east) bank of the Medway in Limehouse Reach, a section described by Hughes (*in* Whitaker 1872, p. 28; *see also* Jukes-Browne 1904, p. 164) formerly exposed 'in the cliff' about 14 ft of chalk, with a hard bed (1 ft 3 in) and 2 ft of underlying chalk which seem to be referable to the top of this zone, beneath 11 ft of Coranguinum beds (*see* p. 50). This northward re-appearance of the zone is apparently due to a north-westerly prolongation of the Luton valley anticline.

In the Upper Chalk area on the right bank of the Medway, chalk of the Cortestudinarium Zone crops out widely and occupies many of the valley slopes at some distance from the Tertiary outcrop. The lower-lying parts of Rochester and the town area of Chatham are built largely on this zone. Also the old chalk quarry ('Dunstall's') at Chalk Pit Hill, 650 yd S.E. of Chatham Station, gave a fossiliferous section through most of the zone described by Jukes-Browne (1904, p. 162). The *Micraster* fauna of the topmost part of the 63 ft of flinty, variable chalk described shows that the top beds of the zone are reached. Nevertheless, the Cortestudinarium Zone is here, as east of Luton, at a higher level than a regular dip would have carried it and affords a further example of the influence of the Luton valley fold. In the road-cutting up Chatham Hill, about three-quarters of a mile E. by S. of Chatham Station, at an O.D. level below 150 ft, three layers of yellow nodular chalk, the middle one the strongest, crop out at intervals of 6 ft and 9 ft in downward succession, separated and underlain by softer chalk with flints. Jukes-Browne correlated these layers with three similar beds in the top beds of the Cortestudinarium Zone of the large Luton pits (*see below*). The thicknesses of intervening chalk, however, do not tally in the two localities and *Micraster* collected from the road-cutting suggests these beds are somewhat lower in horizon, as also they are in topographical level. It is probable that, though thin but distinct limestone beds are a feature of the zone and may define its top, considerable lateral variation in individual bands must occur.

Three large disused chalk-pits on the north-east side of the Luton valley are situated, above Beacon Road, in the area between Beacon Hill and Chatham Hill, about 1¼ miles E.S.E. of Chatham Station. Together these give sections of the top of the Cortestudinarium Zone and the bottom of the Coranguinum Zone but the north-westerly pit showed only about 6 ft of the former (Jukes-

Browne saw 10 ft) and the south-easterly one is entirely in the latter (*see* p. 51). Jukes-Browne gave a detailed section of the middle pit (just below the school on the Rainham Road) and puts the top of the Cortestudinarium Zone at the highest of the three hard yellow bands (A, B, C in the section below). This classification is confirmed by the presence of *Micraster coranguinum* in the beds just above the top hard band of the north-westerly pit (*see* p. 51).

Hughes (*in* Whitaker 1872, p. 28) mentions a hard 'porcellanous knobbly' bed, comparing it with the bed in the section he describes at Limehouse Reach. The following section of the middle pit is abridged and modified from that of Jukes-Browne. It shows a greater thickness of the Coranguinum Zone than is recorded by Jukes-Browne, who, however, apparently saw a greater thickness of the lower beds than is now visible.

Coranguinum Zone, 62 ft (*see also* p. 51)	Ft
Flinty soft chalk with some firmer layers	50
Blocky chalk with flints, becoming firmer and rougher, with hard lumps enclosed in a softer matrix in the lowest foot	12
Cortestudinarium Zone, 33 ft	
C. Very hard compact yellowish band	1¼
Chalk with layers of flints; lumpy and rough chalk at the top and the bottom	14½
B. Bed of yellowish nodular chalk with softer chalk between the nodules	1
Soft chalk with two marked flint layers and an indistinct pale yellowish nodular bed 1 ft 6 in down	8½
A. Bed of hard yellowish nodules in a softer matrix	1
Rough lumpy chalk	1¼
Bed of nodules (paler yellow) in soft matrix	1
Softer chalk with layers of flint	4

Ash Tree Lane, climbing due north from the Luton valley to join the Rainham Road, cuts through variably rough and massive chalk in which the outcrop of the yellow limestone C was noted at about 230 ft O.D.

South of the town area of Rochester and Chatham, Cortestudinarium chalk has been recorded in a number of exposures on the east side of the Medway valley, in the dry-valley systems and also capping the chalk escarpment.

The deep disused pit 100 yd N. of the church at Borstal exposed the following Cortestudinarium chalk above that of the Planus Zone (*see* p. 41):

	Ft
Soft chalk with a few brown lumps; bands of nodular flints	10
Rather lumpy chalk with flints	8
Hard yellow smooth-fracturing band	1
Massively-bedded chalk with many nodular flint bands	10
Brown nodular bed	1½
Rather lumpy chalk	8
Thick seam of tabular flint	

The road-cutting 400 yd S.W. of Borstal Church showed the following section of chalk, disturbed by small faults:

	Ft
Soft chalk	2
Very hard yellowish nodular chalk enclosing a particularly hard and compact band about 1 ft thick	4
Lumpy chalk with nodular flints	7(?)
Intensely hard yellow compact bed	1
Lumpy chalk with bands of flints	12

Whitaker (1872, p. 29), compared the nodular chalk here with 'chalk-rock'; but decisive faunal evidence places the beds in the Cortestudinarium Zone. At Fort Borstal, a quarter of a mile E.S.E. of the above, Cortestudinarium Zone fossils recorded from the trench around the fort (*see* Jukes-Browne 1904, pp. 160, 168) indicate the top beds of the zone. Lumpy chalk, with an intensely hard smooth yellow rock-band, seen at the top of the road-cutting 130 yd E. of Ringshill Place is assigned to this zone, but without direct faunal evidence, as also is an overgrown pit 350 yd S.E. of this section.

In the dry-valley S.S.E. of Nashenden Farm a section on the east side showed chalk which yielded no fossils but appeared to belong to the lower part of this zone. This was in a small pit and a lane-cutting above it about 600 yd N.N.W. of Bridgewood Gates, where were exposed some 42 ft of chalk with flint bands and four courses of yellowish compact or nodular rock. In the upper reaches of the Snodhurst valley, the small pit on the east side about 750 yd S.E. of Bridgewood Gates exposed about 9 ft of chalk with flints, including a very prominent band marking the base of the zone, 2 ft from the bottom of the pit. Where the valley sides are cut into by the road at Snodhurst chalk of this zone is exposed on both sides. The best section was seen on the north side, where 52 ft of variable chalk with flints and four very hard yellow nodular beds are referable to the Cortestudinarium Zone overlain by Coranguinum chalk, mainly on lithological evidence and the presence of a 1-ft band of hard yellow limestone at the top closely comparable with the bed in a similar position in the Luton pits (p. 46). At 70 yd S.E. of the road-junction at Walderslade Bottom, the disused chalk pit (noted on p. 43) exposed the following:

	Ft
Cortestudinarium Zone, 22 ft	
Soft chalk with flints and common *Inoceramus;* a band of large flints near the top	8
Similar mainly blocky chalk, with nodular flints in all but the top 3 ft	12
Hard nodular rock-band, with sponges and common *Echinocorys* and *Micraster*	2
Planus Zone, 15 ft (*see also* p. 43)	
Flinty mainly soft chalk	2
Brown spongiferous rock-band, variably developed and grading into the beds above and below	1
Mainly soft rough chalk with flint bands	12

Specimens of *Micraster* from the upper rock-bed show a distinct advance in evolutional characters over those from the beds below, trends which are further emphasized in specimens from higher levels. A northerly dip of 3° or more seen here is one feature of the local steepening which brings chalk of the Cortestudinarium Zone down to the valley floor a little to the north. The cutting where Walderslade Road climbs the steep north-west side of the valley exposed, rather poorly, 80 ft of unfossiliferous chalk, with flint bands, most of which must belong to the Cortestudinarium Zone, though chalk of the succeeding zone probably caps it. Farther down the valley, 350 yd N.E. of the chapel at Walderslade a small temporary excavation, at about 260 ft O.D., yielded Cortestudinarium Zone fossils. Beyond this again, 200 yd N.E. of Settington, many fossils were obtained from this zone in an old chalk pit exposing 45 ft of rather lumpy chalk with regular but weakly-developed bands of nodular flints. About 30 ft down a massive very hard and compact nodular bed, up to 10 ft thick, contains *Echinocorys* and *Micraster* in abundance.

Chalk of the Cortestudinarium Zone occupies the southern part of the Luton valley and its tributary valleys and extends beneath the Clay-with-flints of the plateau area W. and S.W. of Lidsing. Unfossiliferous sections in this area assigned to the zone on lithological evidence or calculation of position relative to known horizons are: the cutting into the hillside at 300 ft above O.D. on the road from Darland Hill to Speeks Bottom, which shows 16 ft of flinty chalk with compact yellowish hard beds; a small pit 350 yd S.E. of the buildings at Speeks Bottom showing 8 ft of soft flinty chalk; and rough chalk with flints exposed beneath loamy drift in diggings, on the spur of the hill, about 350 yd S.E. of Capstone Pumping Station. A small pit, showing 8 ft of flinty chalk, 100 yd E.S.E. of Gibraltar Farm yielded *Micraster praecursor* characteristic of the top of the zone; also, on the south side of the road 1200 yd W.S.W. of the inn at Lidsing, a characteristic *M. praecursor* was obtained from a temporary excavation, through the Clay-with-flints. About 500 yd E. of Halsted and 90 yd S.E. of the cross-roads an old excavation exposed beneath the Clay-with-flints some 25 ft of weathered chalk with nodular flints with a band of nodular chalk with sponges about 15 ft down, all apparently in the Cortestudinarium Zone.

The more southerly portion of the system of valleys S.E. of Bredhurst is to a large extent cut in Cortestudinarium chalk. A disused pit, on the west side of Lidsing Road, 700 yd S. by W. of Halsted exposed 15 ft of weathered flinty chalk with a 1-ft hard brown spongiferous band in the middle. The uppermost hard bed encountered in the well in Friends Wood (p. 44), should probably be included in this zone, together with 55 ft of chalk above it and probably some of the chalk below. About a third of a mile S. by W. of Dunn Street an old pit showed about 8 ft of soft chalk of this zone containing large irregular nodular flints with pieces of fossil shell frequently associated. In the middle a band with common large *Echinocorys* was noted. On the same side of the valley more than a quarter of a mile to the N.E. and about 400 yd S.E. of Dunn Street two old pits each exposed about 15 ft of similar chalk and a 1-ft hard yellowish nodular rock-bed which appears common to both. The beds in the more northerly pit showed an interesting lateral variation; of two rock-beds about 6 ft and 12 ft respectively from the top, the lower one fades out westwards, while the upper increases in distinctness. Also yellowish nodules, with sponges, are scattered throughout the chalk between the two beds. The pit 100 yd to the south exposed at the top a band of very hard nodular rock probably corresponding with the lower band of the northerly pit, while about 6 in of intensely hard nodular rock with sponges and pyrite, the latter a fairly common feature of the rock-beds in this zone, interbedded with softer chalk, was noted 350 yd S. of Bredhurst Church. On the northern side of the next valley to the south, about 1050 yd S. by E. of Bredhurst Church, the lane-cutting exposed 32 ft of chalk, with bands of flints, of the Cortestudinarium Zone. Of three small pits near Scragged Oak, the first, on the edge of a wood, about a quarter of a mile N.N.E. of the hamlet and the second, about one-eighth of a mile east of the hamlet, both exposed flinty chalk with *Echinocorys* of a gibbous form; the third, 300 yd E. by N. of the hamlet, showed a 20-ft section with bands of large flints. In the road-bank on the steep valley side a quarter of a mile E.S.E. of Kemsley Street, a 6-in bed of very hard nodular rock about 10 ft down may mark the top of the zone. A disused pit 500 yd N.N.W. of Cockhill showed the following section, in which the rock-bed at the top contains *Micraster praecursor* of an evolutionary stage indicating the top beds of the zone:

	Ft
Soft weathered chalk with flints	3
Hard brown and yellowish nodular rock	2
Alternating courses of soft white chalk and rather lumpy less white chalk; many bands of large flints; *Micraster* common in the lower part	24
Chalk face obscured	12
White chalk with flints	3
Hard nodular rock with intensely hard yellowish and brown cores; numerous fossils, including *Micraster cortestudinarium*	8

A small pit on the east side of the valley about half a mile S. by E. of Cockhill exposed about 12 ft of chalk with flints in bands 2–3 ft apart, but yielded no fossils. As the main valley past Queen Down Warren descends towards the Tertiary outcrop at Hartlip, chalk of the Cortestudinarium Zone gradually dips until it lies beneath the valley floor at the north-east end of the Warren. East of Stockbury chalk of the Cortestudinarium Zone crops out in the lower parts of another dry-valley system. A small pit 700 yd S.S.W. of the inn (Three Squirrels) on the Sittingbourne road S. of Stockbury showed 15 ft of variable chalk, flinty near the top and bottom and with ill-defined but very hard yellowish nodules in the lowest 8 ft, in which also *Micraster* is common. A pit 700 yd S.S.W. of Stockbury Church yielded many fossils, including *Micraster praecursor* and *M. cortestudinarium*, from 15 ft of flinty chalk, rough and lumpy in the top half and very hard and rocky in the lower half, with some softer chalk matrix. Towards Bredgar a pit N.W. of Dean's Hill and 650 yd E.S.E. of Littlepett, yielding *Micraster cortestudinarium*, exposed hard and massive chalk containing irregular black flints; similar chalk was seen in a pit 500 yd S.S.W. of Norton Green and in pits along the continuation of the hillside for about half a mile north-west of Dean's Hill. A pit 480 yd S.E. of Magpie Hall over a mile S.E. of Stockbury showed 3 ft of hard massive chalk overlain by 6 ft of softer chalk with bands of flints.

Along the Chalk escarpment a capping of Cortestudinarium chalk is exposed in a few places; in the lane-cutting high on the scarp face about 700 yd north of the church at Burham village, there were exposed rather more than 20 ft of chalk with an intensely hard compact yellowish rock-bed, up to 3 ft thick, in the middle; as shown by palaeontological evidence the base of the zone is below this rock-bed. Whitaker (1872, p. 29) compared the hard bed with 'chalk-rock' but was uncertain of its zonal position. Jukes-Browne (1904, p. 158) recorded *Micraster cortestudinarium* from a small roadside pit formerly to be seen about 300 yd S. of the Upper Bell Inn at Bluebell Hill. About 9 ft of soft chalk with flint bands and an abundance of polyzoa were noted at the top of an exposure about 400 yd N.N.E. of the Lower Bell (p. 43). The track descending the scarp from Westfield Wood has already been mentioned under the Planus Zone (p. 43). At about 600 ft O.D. occurs a soft flinty chalk underlain by hard yellowish lumpy chalk.

Coranguinum Zone: The remaining chalk exposed in the area of the Chatham sheet is all of this zone. It is present on the bank of the Thames at East Tilbury (Dewey and Bromehead 1924, p. 35) and also forms the Chalk mass of the Cliffe area, where about two-thirds of a mile W.S.W. of the village the large disused Francis' Cement Works Pit showed a section of 50 ft or more in soft chalk with lines of flints. The beds are in the Coranguinum Zone, although Jukes-Browne

(1904, p. 166) following Dibley, suspected the presence of *Uintacrinus* or *Marsupites* in this region. Other large quarries extend along the south side of the road to the marshes, about a mile south-west of Cliffe. An old pit in this zone is situated a quarter of a mile W.S.W. of Cooling Castle. Further old pits on the northern slope and other parts of the Cliffe ground are mainly overgrown.

In the main mass of Coranguinum chalk west of the Medway there are numerous small pits, some of them much degraded and overgrown, and one or two important large ones. In the Shorne district sections were seen 250 yd west of Green Farm where 30 ft of chalk with large flints were noted; 100 yd south and again 650 yd E.S.E. of this farm, 350 yd S.E. and 550 yd south by east of the Duke of York Inn on the Rochester–Gravesend road and also 800 yd W.N.W. of the church just on Sheet 271. In the Higham area a 25-ft face 850 yd south of Higham Upshire Church, two old pits near the Pumping Station three-quarters of a mile S.W. of the church and a pit showing 20 ft of massive chalk with flint bands 200 yd east of the Stonehorse Inn and 1⅓ miles east of the church are all in Coranguinum chalk. The latter exposure was described by Jukes-Browne (1904, p. 165), who mentioned a yellowish nodule bed 8 ft from the top. The fauna indicates upper Coranguinum Zone. Other sections are: an old pit in the railway-cutting 600 yd west of the Stonehorse Inn; a pit three-quarters of a mile N.E. of Higham Upshire Church; in the railway-cutting near Higham railway station and two old pits, 300 yd S.W. and 600 yd south by east of the station.

Sections in pits near the Watling Street west of Strood were seen 100 yd west of Park Pale, about a quarter of a mile N.E. of the same and 100 yd south of Chapter Farm, the latter with 40 ft of massive chalk with flints. On the north side of the tracks crossing the valley south of Head Barn Wood two pits 100 yd apart showed 20 ft or more of massive chalk with large flints in bands at intervals of about 10 ft, separated by chalk with scattered flints.

In the Strood district Coranguinum chalk is probably reached at the top of the large workings at Wickham Cement Works, west of Temple Marsh and sections occur in two old pits north of the junction of the Gravesend road with the Watling Street, on the west side of Strood. At Frindsbury a small section just below the Thanet Beds was noted 1100 yd W.N.W. of the church, and another 500 yd west by north of the church adjoining the Church of the English Martyrs in Mill Road. Large sections occur at the tunnel a quarter of a mile north of Strood Junction Station and in the deep excavation at the adjacent sidings. Extending south-east from Frindsbury Church, the more accessible section in the great Strood Quarry north of Limehouse Reach has been enlarged over a period of many years' working (Plate IIA). Fossils from this 100 ft section, entirely in Coranguinum Zone, are listed with the description given by Jukes-Browne (1904, p. 164); the section practically reaches the base of the zone. The top 11 ft of the Limehouse Reach cliff section (p. 45) are in the basal beds of this zone. About half a mile E. by N. of Frindsbury Church a disused pit on the north side of Whitewall Creek below Tower Hill, Upnor, showed 50 ft of chalk beneath the Thanet Beds. Jukes-Browne (1904, p. 165) recorded high-zonal *Micraster coranguinum* and other fossils. Apart from some yellow lumps at the top the chalk is soft and white, with many layers of flints and some scattered flints.

East of the Medway and in the largely built-up area, extending from Rochester through Chatham and Gillingham towards Rainham, the high ground of Rochester town and the adjacent part of Chatham is capped by chalk of this zone. In and around Gillingham railway-cuttings expose the Chalk in a number of places and there were formerly other sections in old pits and in brickyards where overlying Brickearth and Thanet Beds had been removed. Dibley (1918, p. 71) recorded typical *Micraster coranguinum* from excavations at Gillingham Station. A pit one-third of a mile S.E. of Gillingham Church showed a 70 ft section in soft chalk with many layers of flints (Jukes-Browne 1904, p. 164). The chalk immediately underlies the Thanet Beds and fossils indicate that the horizon is well up in the Coranguinum Zone, although Dibley concluded the contrary from the fact that he found no specimens of *Conulus*. About half a mile S.W. of Twydall two pits on either side of Eastcourt Lane exposed chalk with flint bands at intervals of 4 ft or 5 ft, the one on the east side showing a 24-ft section with the beds dipping 3° north-north-east. The large old quarry 250 yd S.E. of Twydall exposes the junction with the Thanet Beds and cuts deeply into the top beds of the Chalk.

South of Rochester, some 20 ft of unfossiliferous chalk irregularly exposed high on the valley side about half a mile south-south-east of Fort Bridgewoods are probably referable to the bottom of the Coranguinum Zone, being clean and soft to brittle in type, with tabular and nodular flint but no hard beds in the chalk. Similarly the top 50 ft of chalk in the road-cutting north of Snodhurst (*see also* p. 47) may also be placed in this zone, which appears to occupy the high ground about the Maidstone Road, between these localities.

South-east of Chatham, of three large disused pits on the north-east side of the Luton valley between Chatham Hill and Beacon Hill (p. 45) the north-westerly pit (300 yd W.N.W. of the School) showed about 35 ft of Coranguinum chalk, and the middle pit 62 ft; the south-easterly one, at Beacon Hill, is entirely in the Coranguinum Zone showing about 65 ft of mainly soft blocky chalk divided by a very conspicuous band of semi-tabular flint about 35 ft down, above which other prominent flint bands are on an average 4 ft or 5 ft apart, but below it flints are more scattered and nodular. Three small pits in the area south of Capstone, a quarter of a mile N.N.E. of the church at Hempstead, about the same distance west, and 550 yd N.E. of Lower Shawstead Farm, exposed chalk of similar type as did an old pit west of Wigmore and a quarter of a mile E.S.E. of the church at Hempstead. Three pits north-east of Rainham Park, respectively about a quarter of a mile W.N.W., half a mile W. and half a mile S.W. of Siloam, exposed soft flinty chalk with very scarce fossils but with many bands of large nodular flints. On the north-west side of Rainham two good sections yielding characteristic fossils were examined, the first, half a mile east of Rainham Mark, showed a 50 ft face with prominent flint bands and the second, an old quarry a quarter of a mile N.W. of Cozenton, 70 ft of soft clean white chalk with many flint bands, averaging 4 ft apart. The large pit, 40 ft deep, 650 yd north of Rainham Station and another pit half a mile north-east of the station showed chalk high in the zone and a third pit, disused and known as the 'Vineyard Pit', two-thirds of a mile east of the station, is dug to about 30 ft in chalk beneath the Thanet Beds.

At Walderslade a temporary exposure 130 yd north-north-east of the road-junction at Walderslade Bottom yielded fossils, including *Micraster*, indicating the base of the Coranguinum Zone and probably the chalk at the top of the road-cutting (*see* p. 47) on the other side of this valley also includes some Coranguinum Zone, in conformity with minor folds described above

(p. 43) which also may bring in Coranguinum chalk as in a small pit one-third of a mile N.W. of Gibraltar Farm. In the Lidsing area sections in two disused pits 100 yd apart, three-quarters of a mile N.E. of the inn, exposed soft chalk with scattered flints, and pits 400 yd N.N.E. and 100 yd south of this inn, and a temporary excavation 200 yd north by west of Halsted all showed that chalk of this zone probably underlies the Clay-with-flints.

East of Bredhurst a small pit, on the north-east side of the road, 350 yd E.S.E. of Kemsley Street, another pit on the opposite side of the road, together with the top 10 ft in the road-cutting, an old pit capped by Clay-with-flints 350 yd N.E. of Farthing Corner, and two pits at Matts Hill, 50 yd S. and 200 yd S.W. of the farm house, all exposed chalk of the zone, there being in the last named 18 ft of soft chalk with rather indistinct bands of flints, abundant fragments of *Inoceramus* shell, and sparing representatives of the zonal fauna. Between Matts Hill and Hartlip three good sections were seen. In Queen Down Warren, 700 yd east by south of Matts Hill, an old chalk-pit showed the following:

	Ft
Soft white chalk with some harder lumps, in vaguely defined courses alternating with hard massive somewhat nodular chalk; flints scattered and in bands averaging 4–5 ft apart	27
Brown-stained nodular course	2
Conspicuous band of large nodular flints	
Variable chalk and flints	10
Thin marly seam	
Flinty chalk in rough courses as in the upper part of the section ..	21

Only *Inoceramus* fragments were seen in the top 27 ft but below this *Micraster coranguinum* and tall domed types of *Echinocorys scutata* occur; at the north-east end of Queen Down Warren an old pit 550 yd south-east of Oak Barn showed a 20 ft face of soft chalk with many flint bands and yielding fairly common *Micraster* and *Echinocorys* in the lower part. The third pit, in the valley 200 yd east of the last named exposed 26 ft of similar beds but with ill-defined harder bands in the lower half. Fossils, other than *Inoceramus* fragments, were only found below a thin marly seam about 9 ft up. At Cowstead, adjoining the farm, an old 20 ft pit showed a good deal of lateral variation in the development of individual flint bands, while about half a mile to the N.N.E. two pits on either side of the road to Lower Hartlip showed firm blocky chalk with black flints, the western pit yielding the zonal fossil again found a quarter of a mile N.N.E. of Plumtree Bottom.

In the valley south of Stockbury an old pit about 350 yd south of South Street exposed 20 ft of soft chalk and flints low in the zone. North-east of Stockbury, in the same valley, a pit 200 yd W.N.W. and another 300 yd S.S.W. of Danaway both showed firm chalk with layers of flints, mainly 6 ft to 8 ft apart.

Between Borden and Bredgar, in an area of comparatively bare chalk, the only exposures seen were in various small and degraded pits. South of the Watling Street in the neighbourhood of Sittingbourne a number of abandoned pits are all dug in flinty chalk, sometimes massive but often broken up into small blocks. Of these pits, one about 300 yd south of the road-junction at Chestnut Street and another, 650 yd E.N.E. of Borden Church each exposed about 12 ft of fairly massive chalk with black flints, dipping north-east at about 2°. Pits 200 yd west of Borden Lane, near the junction with the London Road at Chalkwell and a newer pit about 300 yd north-north-west of Chilton yielded the zonal fauna. About a third of a mile north of Highsted Forstal, of two large pits dug for cement manufacture one on the west side of the road, about 80 ft deep, showed chalk with bands of flints and both pits yielded many specimens of *Micraster coranguinum*, *Conulus* and *Echinocorys*. Of other pits near Highsted Forstal one about half a mile S.S.E. exposed 20 ft of blocky chalk with flints and another, 600 yd S.W. of Woodstock, showed a section in massive chalk.

In the Rodmersham district a number of small abandoned chalk-pits including those respectively about 400 yd east of the church, 200 yd N.N.E. of Dully, 350 yd north and 600 yd north by east of Bargains Hill all exposed massive chalk, with bands of black flints, yielding the zonal fauna.

North of the Watling Street large pits south of the railway at Frognal exposed the chalk, with an uneven surface beneath flinty brickearth, and firm chalk with flints overlain by Thanet Beds was seen 750 yd south-east of Teynham Station and 100 yd north of Mockbeggar.

On the south side of the Watling Street a pit 300 yd N.N.W. of Upper Newlands exposed blocky chalk with irregular flints and a strong band of flints near the bottom; another pit 350 yd N.N.E. of Sundries showed about 15 ft of chalk beneath brickearth; near Lynsted small sections were seen 180 yd north of the church and 750 yd east by north of the church; while 500 yd W.N.W. of Tickham up to 20 ft of chalk with flints were noted.

S.C.A.H.

REFERENCES

DEWEY. H. and C. E. N. BROMEHEAD. 1924. Geology of the Country around Dartford. *Mem. Geol. Surv.*

DIBLEY, G. E. 1900. Zonal Features of the Chalk Pits in the Rochester, Gravesend and Croydon Areas. *Proc. Geol. Assoc.*, vol. xvi, p. 484.

—— 1900. Excursion to Strood and Halling. *Proc. Geol. Assoc.*, vol. xvi, p. 532.

—— 1904. Excursion to Holborough and Burham. *Proc. Geol. Assoc.*, vol. xviii, p. 474.

—— 1912. Note on the Chalk Rock in North Kent. *Geol. Mag.* New Series, Decade V, vol. ix, p. 372.

—— 1918. Additional notes on the Chalk of the Medway Valley and other areas. With Palaeontological Notes and Appendices by G. C. Crick and R. B. Newton. *Proc. Geol. Assoc.*, vol. xxix, p. 68.

HOOD, A. W. 1884. The Chalk of the Medway Valley. *Rochester Naturalist*, vol. i, No. 4, p. 57.

JUKES-BROWNE, A. J. 1903, 1904. The Cretaceous Rocks of Britain: vol. ii (1903), The Lower and Middle Chalk of England; vol. iii (1904), The Upper Chalk of England. *Mem. Geol. Surv.*

WHITAKER, W. 1872. The Geology of the London Basin. *Mem. Geol. Surv.*, vol. iv.

OTHER WORKS ON THE CHALK OF THE CHATHAM DISTRICT:

BARROIS, C. 1876. Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande. *Mém. Soc. Géol. Nord.*, vol. i. (Medway Valley on p. 136.)

BENSTED, W. H. 1862. Notes on the Geology of Maidstone. *The Geologist*, vol. v, p. 294.

BIRD, C. and W. F. HUME. 1895. Excursion to Burham and Aylesford. *Proc. Geol. Assoc.*, vol. xiv, p. 194.

DIBLEY, G. E. 1899. Excursion to Cuxton and Burham. *Proc. Geol. Assoc.*, vol. xvi, p. 249.

—— 1905. The Fauna and Lithological Features of the Chalk in the Rochester District. *Rochester Naturalist*, vol. iii, p. 297.

—— 1907. Excursion to Rochester, Wouldham and Blue Bell Hill. *Proc. Geol. Assoc.*, vol. xx, p. 178.

—— 1909. Excursion to Strood and Cuxton. *Proc. Geol. Assoc.*, vol. xxi, p. 45.

—— 1913. Excursion to Borstal and Burham. *Proc. Geol. Assoc.*, vol. xxiv, p. 54.

—— 1922. Excursion to Blue Bell Hill, Rochester. *Proc. Geol. Assoc.*, vol. xxxiii, p. 75.

—— and L. F. Spath. 1926. Excursion to Burham and Aylesford, Kent. *Proc. Geol. Assoc.*, vol. xxxvii, p. 432.

Hepworth, J. 1913. *Rochester and District. A Sketch-Guide to its Geology, Flora and Fauna.* Rochester.

Priest, S. and F. J. Epps. 1935. Field Meeting at Higham and Shorne, Kent. *Proc. Geol. Assoc.*, vol. xlvi, p. 61.

Topley, W. 1875. The Geology of the Weald. *Mem. Geol. Surv.*, (Chloritic Marl at Burham, p. 153).

Vine, G. R. 1893. Report . . . on the Cretaceous Polyzoa. *Rep. Brit. Assoc.* (Edinburgh 1892). Section C, p. 301. (Chatham Chalk on p. 306, *et seq.*)

Whitaker, W. 1889. The Geology of London and of part of the Thames Valley, vol. i, Descriptive Geology. *Mem. Geol. Surv.* (Kent Chalk on p. 82.)

Chapter VI

PALAEONTOLOGY OF THE CHALK

Chatham is the centre of an area of great interest in Chalk palaeontology. The Lower Chalk and Middle Chalk are magnificently exposed in the numerous large quarries around Burham, Cuxton and Halling and the almost continuous section from the Gault to the base of the Upper Chalk in the quarries around Bluebell Hill, though now much decayed, constitutes one of the finest inland exposures of Cretaceous rocks in the country. The Upper Chalk may still be studied in many pits scattered over the dip-slope, especially around Cliffe and Sittingbourne, but the growth of the Medway towns has obscured several once-famous sections in Strood, Frindsbury and the southern and eastern parts of Chatham.

Much of our knowledge of the palaeontology of the Chalk of this area has resulted from the work of two local amateur geologists. W. Gamble, a grocer of Chatham, devoted his attention chiefly to the Upper Chalk (Planus and Cortestudinarium zones) of Luton and Borstal. His collection, now in the Geological Survey Museum, includes many polyzoa. G. E. Dibley, a schoolmaster of Sydenham, and, after retirement, Director of the Eastgate Museum, Rochester, worked more widely. His principal collection is in the British Museum (Natural History), and many of his fossils were illustrated by G. C. Crick, E. T. Newton, R. B. Newton, T. H. Withers, A. S. Woodward and others.

Lower Chalk. The Lower Chalk yields its characteristic ammonites, including *Schloenbachia* in the lower and *Acanthoceras* in the upper part. The invertebrate fauna as a whole is that typical of the formation in southern England and the number of Cirripede species recorded by Withers (1935) is probably to be attributed to the thorough collecting of Dibley, rather than to any concentration through natural causes. The specimen of *Epiaster distinctus* (Agassiz) from Bluebell Hill figured by Dibley (1918) is unique in England. Its occurrence points to an affinity with the fauna of the Chalk of France which is emphasized by certain species recorded from higher zones.

The Lower Chalk (in particular the Subglobosus Zone) is of special interest for the large number of vertebrate fossils it has yielded. Fifty-five named species of fishes are recorded by A. S. Woodward (1902–11), principally from the Dibley and Harford Collections, while *Ctenothrissa microcephala* (Agassiz) and *Ptychodus decurrens* Agassiz are said by Dibley to serve as 'zonal fossils' of the upper part of the Lower Chalk at Wouldham. The reptilian fauna includes the giant marine lizard *Mosasaurus* (geologically the earliest record of the genus in Europe), the related forms *Dolichosaurus longicollis* Owen and *Coniasaurus crassidens* Owen, and various marine turtles and Pterosaurs.

Middle Chalk. The Middle Chalk is also remarkably rich in fossil fishes and 23 species are recorded by Woodward (1902–11). The invertebrate fauna is not remarkable, though the occurrence of the rare Hippuritid *Durania mortoni* (Mantell) may be mentioned as further evidence of French affinity in the fauna. The rare gastropod *Hipponyx dibleyi* Sherborn was described from the Terebratulina Zone of Cuxton and the complete 'crown' of the Cirripede

Stramentum pulchellum described by G. B. Sowerby jun. in 1843 was collected in the Labiatus Zone of the same locality, according to Dibley.

UPPER CHALK. In the Upper Chalk the Planus Zone contains no true Chalk Rock such as is developed in Berkshire and Oxfordshire, but the distinctive fauna of this horizon (the Reussianum Fauna) occurs in a number of beds of nodular chalk which range through a large part of the zone. The cephalopods and gastropods are dwarfed in size and generally occur as negative external moulds in the nodules. The coral *Trochocyathus* is locally abundant. A jaw of *Mosasaurus gracilis* Owen is recorded from this zone at Cuxton.

The numerous polyzoa collected by W. Gamble from the Planus Zone and the succeeding Cortestudinarium Zone have not as yet received the specialized study they deserve. The remaining fauna of the Cortestudinarium Zone is not remarkable.

The chalk of the Coranguinum Zone is unfossiliferous in the lower part, but fossils are abundant and often exquisitely preserved towards the top of the zone. The sea-urchin *Conulus* occurs in many shape-variations, from the small, spheroidal *C. globulus* through rounded, subconical types (*C. vulgaris*, *C. subconicus*) to the familiar 'dunce's-cap' forms (*C. albogalerus*). Whether the differences in shape expressed by these names are linked with structural differences or with any stratigraphical sequence is not known. *C. raulini*, a species apparently unrelated to the *C. globulus-albogalerus* series, is known from Strood, and is another southern element in the fauna.

The rare sea-urchin *Echinothuria floris* S.P. Woodward, of which only some half-dozen specimens are known, all from the Coranguinum Zone of Kent, was first found at Higham. This is the only known Cretaceous member of the Echinothuriidae, a family of world-wide occurrence at the present day and almost exclusively confined to great depths. In these sea-urchins the test is flexible and composed of thin, overlapping plates, a feature otherwise only known in Palaeozoic forms.

The sea-urchin *Micraster* can be used to discriminate horizons in the Upper Chalk by means of the progressive changes in the features of the test studied by Rowe (1899; *see* Dewey and Bromehead 1924, p. 18). The subgenus *Isomicraster* ('*Epiaster gibbus*' auctorum *non* Lamarck sp.) is characterized by a pyramidal profile with the periproct placed so close to the lower surface that the subanal fasciole is obliterated. Normal, fasciolate Micrasters from all horizons above the base of the Cortestudinarium Zone show a marked hypertrophy of those pores of the hinder pair of ambulacra which are included within the fasciolar ring. The fact that exactly similar pores occur in *Isomicraster* shows that these forms are descended from normal *Micraster* and that they should not be classed with the true *Epiaster*. *Isomicraster* is further distinguished by a relatively sudden increase in elaboration of the anterior ambulacrum as compared with *Micraster* in the strict sense.

LIST OF FOSSILS

In the subjoined lists there is given first a list of the localities from which fossils have been collected by Survey officers, arranged by zones. The larger chalk quarries, frequently visited in the past, have been known by various names, after those of former proprietors. These names, where known, have been added to the following list of localities. There follows a systematic table of the fauna of the Chalk of this area in which species recorded in the literature are referred to by symbols explained below. The ammonites in this list have been identified by Dr. L. F. Spath, F.R.S., except for those quoted from previously published works. Finally, there are mentioned certain noteworthy fossils which cannot be assigned to particular zones. Reference should also be made to the lists published by G. E. Dibley (1900, 1918), which have not been incorporated here.

No attempt has been made to list the Foraminifera, Polyzoa and Ostracoda, since these groups, though abundantly represented in the Chalk, are incompletely known and their study presents special problems.

A. *List of localities represented by fossils in the Geological Survey Collections*, grouped under six-inch quarter-sheet numbers. Place names referred to appear on the 1-inch New Series Geological Map, Sheet 272.

The registered numbers of the fossils are given in square brackets.

LOWER CHALK

Zone of *Schloenbachia varians*

1. Snodland: Cemetery (*see* Dewey 1924, p. 38). 30 N.E. [C.P. 8–25.]
2. Ditch in base of large pit, W. of tunnel under Pilgrim's Road, 400 yd N.N.E. of Lad's Farm, S. of Upper Halling (*see* Dewey 1924, p. 38). Formerly Lee and Co.'s Pit. 30 N.E. [A.T. 2302–2316.]
3. Railway-cutting, Hale Farm, S.S.E. of Burham. 31 N.W. [⊙2148–2159.]
4. Burham Quarry, lower and upper parts, Bluebell Hill, E. of Burham. 31 N.W. [⊙2399; W.H. 389–391.]
5. Associated Portland Cement Manufacturers' Ltd. railway-cutting, ditch 200–250 yd W. of bridge at bend in Burham–Eccles road, three-quarters of a mile S.S.E. of church at Burham village (Chloritic Marl.) 31 N.W. [A.T. 1977–1997.]
6. Same cutting, lower fork, 100 yd E. of same bridge. 31 N.W. [A.T. 1998–2074, 2245–2252.]
7. Same cutting, 300 yd E. of same bridge. 31 N.W. [A.T. 2075–2108.]
8. Quarry face close to tunnel 400 yd N.E. of Great Culand and three-quarters of a mile S.E. of church at Burham village (*see also* Subglobosus Zone.) 31 N.W. [A.T. 2140–2177.]

Zone of *Holaster subglobosus*

(Localities marked with an asterisk include the Belemnite Marls, Subzone of *Actinocamax plenus*.)

*9. Western end of quarry E. of Pilgrims' Road, Upper Halling (*see* Dewey 1924, p. 38). 30 N.E. [C.P. 1–7.]

*10. Disused quarry (Wouldham Pit, Peters' Pit), E. of Wouldham Hall, and about 1¼ miles S.S.E. of Wouldham (*see also* Middle Chalk, Labiatus Zone). 31 N.W. [⊙2239–2259.]

11. Margett's (Millbay) Chalkpit, N.W. of Burham. 31 N.W. [⊙2276–2300; S.C.H. 1334–1340.]
12. Associated Portland Cement Manufacturers' Ltd. railway-cutting, E. end of lower quarry, 400 yd E. of bridge at bend in Burham–Eccles road three-quarters of a mile S.S.E. of church at Burham village. 31 N.W. [A.T. 2109–2114.]
13. Working face of upper level of quarry, 400 yd E.N.E. of same bridge. 31 N.W. [A.T. 2115–2135.]
14. Burham Chalkpit, Bluebell Hill. 31 N.W. [⊙2160–2179; A.T. 2324–2328.]
15. Quarry face close to tunnel, 400 yd N.E. of Great Culand and three-quarters of a mile S.E. of church at Burham village. 31 N.W. [A.T. 2140–2177.]
16. Disused quarry E. of same tunnel. 31 N.W. [A.T. 2178–2181.]

17. 50 yd E. of tumulus, 1 mile N.W. of Snodland (on Holborough Hill). 31 N.W. [S.C.H. 1441–1443.]
*18. Disused quarries E., N.E. and N. of tunnel, 400 yd N.E. of Great Culand and three-quarters of a mile S.E. of church at Burham village. 31 N.W. [A.T. 2182–2195.]

MIDDLE CHALK

Zone of *Inoceramus labiatus*

19. Wouldham Chalkpit, up to 20 ft above Belemnite Marl (possibly Schoolfarm Lime-Works). 19 N.W. [⊙2263–2275.]
20. Disused quarry (Peters' Pit) E. of Wouldham Hall (*see also* Lower Chalk, Subglobosus Zone). 31 N.W. [Zc. 4919–4920; S.C.H. 1439–1440.]
21. Upper section of large quarry-system (middle level of series of disused pits) about 700 yd W. of Bluebell Hill and 800 yd N.N.E. approximately of Great Culand (No. 1 pit Burham, Bluebell Hill). 31 N.W. [Zc. 1547–1555; S.C.H. 1341–1343; A.T. 2196–2210, 2218–2222.]

Zone of *Terebratulina lata*

22. Disused pit half a mile N.N.E. of Wouldham Church (Tingey's Pit). 19 S.W [S.C.H. 1499–1500.]
23. Summit of hill (Holborough Hill) N.W. of Snodland. 30 N.E. [C.B. 191.]
24. Highest quarry on Bluebell Hill, half a mile N.E. of Great Culand, up to 80 ft above bottom of quarry. 31 N.W. [A.T. 2223–2228, 2243–2244.]
25. Upper stage of quarry N.E. of tunnel, 400 yd N.E. of Great Culand, Bluebell Hill, 50–70 ft above bottom of quarry. 31 N.W. [A.T. 2211–2217.]
26. Small chalk pit above large quarries, half a mile N.E. by E. of Wouldham Hall. 31 N.W. [S.C.H. 1436–1438, 1638.]
27. Burham Upper Quarry, Bluebell Hill. 31 N.W. [⊙2180–2184.]
28. Large pit 250 yd N. of Lower Bell Inn, Burham (*see also* Upper Chalk, Planus Zone). 31 N.E. [S.C.H. 1144–1150.]
29. Old pit 300 yd N. by W. of Lower Bell Inn, 1½ miles S.E. of Burham (*see also* Upper Chalk, Planus Zone). 31 N.E. [S.C.H. 1171–1180.]
30. Old pit 500 yd N. by W. of Lower Bell Inn (*see also* Upper Chalk, Planus Zone). 31 N.E. [S.C.H. 1192–1200.]
31. Old pit approximately 500 yd N.E. by E. of Lower Bell Inn and 1100 yd W.S.W. of Cossington Fields (*see also* Upper Chalk, Planus Zone). 31 N.E. [S.C.H. 1124–1130.]

UPPER CHALK

Zone of *Holaster planus*

(Localities marked with an asterisk have yielded the Reussianum Fauna.)

*32. White Pit (Rugby Portland Cement Co.), half a mile N. by E. of Upper Halling and on S.E. edge of Wingate Wood (Formby's Pit). 18 S.E. [S.C.H. 1617–1634.]
33. Lane-cutting, 700 yd N.N.W. of Upper Halling (350 yd N.N.W. of Upper Halling Court at N.E. corner of Scrub Wood). 18 S.E. [S.C.H. 1635.]
*34. Martin Earle's Pit (Wickham Cement Works), W. of Temple Marsh, Rochester (*see also* Cortestudinarium Zone). 19 N.W. [⊙2321–2337; W.H. 379–388; Z. 3452; S.C.H. 1492–1498, 1640–1641.]
*35. Medway Cement Co.'s pit (Booth's Pit), half a mile S.E. of Ranscombe, S.W. of Rochester and 750 yd N.E. of Cuxton Railway Station. 19 N.W. [⊙2301–2320; S.C.H. 1487–1491, cutting into pit.]
36. High Street, Chatham, near Technical Institute. 19 N.E. [799–800 Gam.]
37. Cuxton. 19 S.W. [Ze. 1702–1703.]
38. Wouldham. 19 S.W. [Zc. 4934–4938.]
*39. Lane, 50 yd W. of Cuxton Church. 19 S.W. [S.C.H. 1501–1505.]
*40. Bores Hole (Whorns Place, Trechmann and Weekes') Pit, W.S.W. of Whorns Place, S. of Cuxton (*see also* Cortestudinarium Zone). 19 S.W. [⊙2400–2413; W.H. 1, 3, 110, 115, 116, 357–374; S.C.H. 1506–1512.]
41. Small pit, 100 yd N.E. of Dean Farm, S.E. of Cuxton. 19 S.W. [S.C.H. 1517–1525.]

42. Track-cutting, half a mile W. of North Halling (550 yd N.E. of White Pit and 600 yd W.S.W. of Sebastopol, North Halling). 19 S.W. [S.C.H. 1526–1531.]
43. Overgrown pit, 200 yd S. of Ringshill Place, Wouldham. 19 S.W. [S.C.H. 1538–1544.]
*44. Old pit, 400 yd N.N.W. of Fort Borstal and 100 yd N. of Borstal Church (*see* Dibley 1912; Borstal Manor Pit of Dibley 1918, not of Dibley 1900). (*see also* Cortestudinarium Zone). 19 S.W. [S.C.H. 1545–1573.]
*45. Old pit, 600 yd N.N.W. of Fort Borstal and 300 yd N.W. of Borstal Church. 19 S.W. [S.C.H. 1576–1582.]
46. Valley through Upper Luton, S.E. of Chatham. 19 S.E. [839 Gam.
47. Road-cutting, East Hill, Chatham. 19 S.E. [S.C.H. 1610–1611.]
*48. Burham Upper Quarry, Bluebell Hill, and half a mile N.E. of Great Culand. 31 N.W. [W.H. 5, 41; ⊙2185–2191; A.T. 2229–2242; S.C.H. 1247–1260.]
49. Small roadside exposure, Bluebell Hill. 31 N.W. [W.H. 4.]
*50. Lane-cutting, 500–550 yd S.W. of Burham Hill and about 700 yd N. of church at Burham village (*see also* Cortestudinarium Zone). 31 N.W. [S.C.H. 1286–1314.]
*51. Lane-cutting (part approximately 400 ft O.D.), 550 yd N. by E. of Scarborough (over half a mile N.W. of Burham) and half a mile W.N.W. of Burham Hill. 31 N.W. [S.C.H. 1315–1333.]
*52. Large weathered block in floor of middle-level quarry, Bluebell Hill. 31 N.W. [S.C.H. 1345–1346.]
53. Shallow pits, 1050 yd N.E. of Cossington Fields and about three-quarters of a mile S.E. of Walderslade Bottom (N.E. of Bluebell Hill). 31 N.E. [S.C.H. 1055–1059.]
*54. Old pit, 450 yd N.E. of Lower Bell Inn and 1200 yd W.S.W. of Cossington Fields (S.W. of Lidsing). 31 N.E. [S.C.H. 1060–1089.]
55. Old pit, 400 yd N.N.E. of Lower Bell Inn and opposite farm, 1400 yd W.S.W. of Cossington Fields. 31 N.E. [S.C.H. 1090–1110.]
*56. Old pit, approximately 500 yd N.E. by E. of Lower Bell Inn and 1100 yd W.S.W. of Cossington Fields (*see also* Middle Chalk, Lata Zone). 31 N.E. [S.C.H. 1111–1123.]
*57. Large pit, 250 yd N. of Lower Bell Inn and 450 yd W. by S. of 56 (*see also* Middle Chalk, Lata Zone). 31 N.E. [S.C.H. 1131–1143.]
*58. Old pit, 300 yd N. by W. of Lower Bell Inn and within 100 yd N.W. of 56 (*see also* Middle Chalk, Lata Zone). 31 N.E. [S.C.H. 1153–1170.]
*59. Old pit, 500 yd N. by W. of Lower Bell Inn and about 100 yd N. of 58 (*see also* Middle Chalk, Lata Zone). 31 N.E. [S.C.H. 1181–1191.]
60. Old pit, 70 yd S. of road junction, Walderslade Bottom and 1670 yd N. by E. of Cossington Fields (*see also* Cortestudinarium Zone). 31 N.E. [S.C.H. 1201–1216.]
61. Small pit, 950 yd W. of road junction, Walderslade Bottom and 750 yd S.E. of Bridgewood Gates (N. of Bluebell Hill). 31 N.E. [S.C.H. 1232–1244.]
*62. Lane-cutting, 650 yd N.E. of church at Burham village and 340 yd S.W. of the Robin Hood and Little John Inn. 31 N.E. [S.C.H. 1261–1278.]
63. Old pit, S.E. of Bredhurst, 600 yd E. of Newlands Wood and 500 yd S. by E. of Lower Cox Street. 32 S.W. [S.C.H. 827–853.]

Zone of *Micraster cortestudinarium*

64. Martin Earle's pit (Wickham Cement Works), W. of Temple Marsh, Rochester (*see also* Planus Zone). 19 N.W. [W.H. 379–388.]
65. Old pit, N. by W. of Court Lodge, Cuxton. 19 N.W. [S.C.H. 1485–1486.]
66. Bores Hole pit (Whorns Place, Trechmann and Weekes'), W.S.W. of Whorns Place, Cuxton (*see also* Planus Zone). 19 S.W. [W.H. 357–374.]
67. Fort Borstal, Chatham. 19 S.W. [552–554 Gam.]
68. Small section in old pit just S.W. of 66 and 150 yd W.N.W. of Sebastopol, North Halling. 19 S.W. [S.C.H. 1532–1536.]
69. Old pit, 100 yd N. of Borstal Church (*see also* Planus Zone). (Borstal Manor Pit of Dibley 1918, not of Dibley 1900.) 19 S.W. [S.C.H. 1574–1575.]

70. Road-cutting, 300 yd N.W. of Fort Borstal and 150 yd S.W. of Victoria Terrace. 19 S.W. [S.C.H. 1583–1584.]
71. Luton pit, Chatham (*see also* Coranguinum Zone). 19 S.E. [W.H. 298–299; 514–551 Gam.; 5–242 Gam. in part.]
72. Beacon Road, Luton, Chatham (northerly pit of Gamble). 19 S.E. [801–826 Gam.]
73. Chalkpit Hill, Chatham (Dunstall's pit). 19 S.E. [W.H. 300–301; 506–509 Gam., 775–798 Gam., 5–242 Gam. in part.]
74. Chatham Hill road-cutting. 19 S.E. [⊙2338–2353.]
75. Chatham. ?19 S.E. [243–505 Gam., 843 Gam.]
76. Old pit, 200 yd N.E. of Settington, 1 mile N. of Walderslade. 19 S.E. [S.C.H. 1585–1606.]
77. Lane-cutting, 500 yd to 550 yd S.W. of Burham Hill and about 700 yd N. of church at Burham village (*see also* Planus Zone.) 31 N.W. [S.C.H. 1281–1285.]
78. Temporary excavation, 970 yd S. by W. of inn at Lidsing, W. of Bredhurst and about half a mile W.S.W. of Dunn Street; 90 yd S.E. of cross-roads. 31 N.E. [S.C.H. 1017–1022.]
79. Old pit, 1070 yd S.S.E. of inn at Lidsing and about one third of a mile S. by W. of Dunn Street. 31 N.E. [S.C.H. 1023–1033.]
80. Old pit, 1100 yd S.E. of inn at Lidsing and about 400 yd S.E. of Dunn Street. 31 N.E. [S.C.H. 1034–1045.]
81. Small pit, 100 yd E.S.E. of Gibraltar Farm and 1450 yd N.N.W. of inn, Lidsing. 31 N.E. [S.C.H. 1046.]
82. Old pit, 70 yd S.E. of road-junction, Walderslade Bottom, and 1670 yd N. by E. of Cossington Fields (*see also* Planus Zone). 31 N.E. [S.C.H. 1201–1216.]
83. About half a mile N. by E. of Walderslade Bottom and 350 yd N.E. of chapel at Walderslade. 31 N.E. [S.C.H. 1231.]
84. Old pit about 1⅛ miles S.W. of Dunn Street and 1000 yd S.E. of Westfield Sole, near Bredhurst. 31 S.E. [S.C.H. 928–930.]
85. Lane-cutting, 1050 yd S. by E. of Bredhurst Church. 32 N.W. [S.C.H. 887–890.]
86. Old pit, 300 yd E. by N. of Scragged Oak hamlet and approximately 500 yd N.W. of Lower Cox Street, S.E. of Bredhurst. 32 N.W. [S.C.H. 895–897.]
87. Old pit, 1100 yd E.S.E. of Kemsley Street and 500 yd N.N.W. of Cockhill, E. of Bredhurst. 32 N.W. [S.C.H. 898–927.]
88. Small pit, 700 yd S.S.W. of Stockbury church and 300 yd E.N.E. of the inn, half a mile S. of Stockbury (Three Squirrels). 32 N.E. [S.C.H. 800–814; Rb. 284–285.]
89. Old pit, 700 yd S.S.W. of Three Squirrels Inn, Stockbury. 32 S.W. [S.C.H. 820–826.]
90. Pit, 1020 yd S.E. of Pett Farm, 300 yd N.W. of Dean's Hill, S.E. of Stockbury. 32 S.E. [Rb. 286–287.]

Zone of *Micraster coranguinum*

91. Old pit, 800 yd W.N.W. of church and 1100 yd S.W. of Crown Inn, Shorne (site on Sheet 271). 10 S.E. [R.M. 2160–2163.]
92. Alpha Cement Works pit, 1 mile S.W. of Cliffe Church and on S. side of road to Cliffe Fort. 11 N.W. [R.M. 2205–2219.]
93. Francis' Cement Works pit (disused), about three-quarters of a mile W.S.W. of Cliffe Church. 11 N.W. [R.M. 2200–2225.]
94. Old pit, a quarter of a mile W.S.W. of Cooling Castle on road to Cliffe. 11 N.E. [R.M. 2200–2204.]
95. Old pit (Stonehorse Pit), about 1⅓ miles E. of church and half a mile W.S.W. of Oakstreet, 200 yd E. of Stonehorse Inn, Higham Upshire. 11 S.W. [⊙2370–2398; W.H. 48; R.M. 2191–2195.]
96. Old pit on S.W. side of Rochester–Gravesend road, 350 yd S.E. of Inn (Duke of York), three-quarters of a mile S.S.E. of Shorne. 11 S.W. [R.M. 2164–2167.]
97. Pair of old pits, 1 mile N.E. of church and 650 yd E.S.E. of Green Farm, Shorne. 11 S.W. [R.M. 2168–2173.]

98. Old pit in garden of and 100 yd S. of Green Farm, Shorne. 11 S.W. [R.M. 2174–2180.]
99. Old pits, E. and W. of road, 1400 yd S.S.W. of church and 800 yd N. of London–Rochester road, near Higham Waterworks, half a mile N. of Higham Upshire. 11 S.W. [R.M. 2183–2188.]
100. Old pit, 850 yd S. of church and 450 yd S.E. of Gadshill, Higham Upshire. 11 S.W. [R.M. 2181–2182.]
101. Old pit in railway-cutting between tunnels, half a mile E.S.E. of Great Hermitage, E. of Higham Upshire. 11 S.W. [R.M. 2196.]
102. Old pit, three-quarters of a mile N.E. of church and a quarter of a mile S.W. of Twogates House, Higham Upshire. 11 S.W. [R.M. 2197–2199.]
103. Near Strood. ?19 N.W. [W.H. 117–121.]
104. Tower Hill, Rochester. 19 N.W. [W.H. 23.]
105. Old pit, on N.E. side of Mill Road, in grounds of Church of the English Martyrs, Frindsbury. 19 N.W. [R.M. 2226–2227.]
106. Ball's Cutting, near Board Schools and Honey's Brickyard, Chatham. ?19 N.E. [608–774 Gam., 841 Gam.]
107. Featherby's pit, one-third of a mile S.E. of Gillingham Church (Pit 46 of Dibley 1918, Gadshill of Jukes-Browne 1904, p. 164). 19 N.E. [601–607 Gam.]
108. Limehouse Reach, Chatham. 19 N.E. [827–833 Gam.]
109. The Quarry, Strood. 19 N.E. [834–838 Gam., ⊙2354–2362; Ze.1748–1750.]
110. Quarry at top of Chatham Hill, Chatham. 19 N.E. [W.H. 22.]
111. Luton Pit, Chatham (*see also* Cortestudinarium Zone). 19 S.E. [514–551 Gam.]
112. Eastern part of old pit, 300 yd W.N.W. of school off Rainham Road above Luton. 19 S.E. [S.C.H. 1616.]
113. Old pit, a quarter of a mile N.W. of Cozenton, Rainham. 20 S.W. [S.C.H. 1483–1484.]
114. Kemp Bros.' pit, half a mile E. of Rainham Mark, W. of Rainham. 20 S.W. [S.C.H. 1475–1482.]
115. South face of pit, 650 yd N. of Rainham Station and 2¼ miles S.W. of Upchurch Church. 20 S.W. [Rb. 281–282.]
116. Old pit, 230 yd E. of Station Road and half a mile N.E. of station, Rainham. 20 S.W. [R.M. 2228–2230.]
117. Vineyard Pit (disused), 500 yd to 700 yd N. of Dover road and Moor Street (on W. side of Moor Street Lane). 20 S.W. [R.M. 2231–2241.]
118. Temporary excavation, 800 yd E. of Westfield Sole and 1000 yd W. of inn at Lidsing, 200 yd N. by W. of Halsted. 31 N.E. [S.C.H. 1047–1049.]
119. Small exposure, 130 yd N.E. of road-junction, Walderslade Bottom, N.E. of Burham. 31 N.E. [S.C.H. 1217–1230.]
120. Old pit and adit, 50 yd S. of Matts Hill and half a mile N.N.W. of Guildsted, E. of Bredhurst. 32 N.W. [S.C.H. 856–866.]
121. Old pit, Queen Down Warren, 700 yd E. by S. of Matts Hill and about 700 yd N. by E. of Guildsted, E. of Bredhurst. 32 N.W. [S.C.H. 867–869.]
122. Old pit, 550 yd S.E. of Oak Barn and about 1000 yd S.S.W. of Hartlip Place, W. of Hartlip. 32 N.W. [S.C.H. 870–876, 1434–1435.]
123. Old pit, 700 yd S.E. of Oak Barn and about 1000 yd S. by W. of Hartlip Place, W. of Hartlip; 200 yd E. of 122. 32 N.W. [S.C.H. 880–882.]
124. Old pit at Cowstead, half a mile N. by E. of inn at Stockbury. 32 N.W. [S.C.H. 877–879.]
125. Ground surface, 400 yd W.N.W. of Hill Green and one-third of a mile E. of Guildsted (E. of Bredhurst), quarter of a mile N.N.E. of Plumtree Bottom. 32 N.W. [S.C.H. 883.]
126. Small pit, 350 yd E.S.E. of Kemsley Street and half a mile E.N.E. of Bredhurst Church, on N.E. side of road. 32 N.W. [S.C.H. 885.]
127. Small pit, S.E. of Rainham Park, about 1½ miles S. of Rainham, and 350 yd N.E. of Farthing Corner. 32 N.W. [S.C.H. 886.]
128. Pit, half a mile S.S.E. of Lower Hartlip and 900 yd W. of Thrognall, on W. side of road to Lower Hartlip, 220 yd N. by W. of Nunfield House. 32 N.E. [Rb. 283.]

129. South face of pit, 650 yd E.N.E. of Borden Church and 500 yd E.N.E. of Harmans Corner. 32 N.E. (Rb. 288–289; R.M. 2247–2255.]
130. Old pit, 150 yd N.W. of Maidstone–Sittingbourne road at third milestone from Sittingbourne. 32 N.E. [R.M. 2242–2246.]
131. Old pit, near road-junction 350 yd S. of South Street, three-quarters of a mile S.W. of Stockbury and half a mile W.S.W. of inn (Three Squirrels), half a mile S. of Stockbury. 32 S.W. [S.C.H. 815–819.]
132. Pit, at angle between Borden Lane and London Road, Chalkwell, Sittingbourne. 33 N.W. [R.M. 2256–2261.]
133. Pit, on E. side of Bell Road and 300 yd N.N.W. of Chilton, S.E. of Sittingbourne. 33 N.W. [R.M. 2262–2263.]
134. Associated Portland Cement Manufacturers' Ltd. pits, 1 mile S. of Sittingbourne, E. and W. of road to Rodmersham Green and one third of a mile N. of Highsted Forstal. 33 N.W. [R.M. 2264–2278.]
135. Old pit, 1100 yd E. of Rodmersham Church and 200 yd N.N.E. of Dully. 33 N.W. [R.M. 2279–2280.]
136. Old pit, 400 yd E. of Rodmersham Church on N. side of footpath to Dully. 33 N.W. [R.M. 2281–2283.]
137. Old pit, 750 yd E.S.E. of church at Green Street, Teynham, and 300 yd N.N.W. of Upper Newlands. 33 N.E. [R.M. 2285–2289.]
138. Old pit in park, 600 yd S.W. of Woodstock and about nine-tenths of a mile S. of Tunstall Church. 33 S.W. [R.M. 2290–2292.]
139. Old pit, 350 yd N. of Bargain's Hill and 1⅓ miles W. of Lynsted Church. 33 S.W. [R.M. 2293–2296.]
140. Old pit, 600 yd N. by E. of Bargain's Hill and 1¼ miles W. of Lynsted Church. 33 S.W. [R.M. 2297–2301.]
141. Old pit, 300 yd S.W. of Nouds Farm (=Newhouse Farm) and five-sixths of a mile E. of Lynsted Church; 500 yd W.N.W. of Tickham. 33 S.E. [R.M. 2302–2303.]

B. *Systematic Table of Fossils*

Fossils collected by Geological Survey officers are indicated by the symbol x in the zonal columns. The other symbols, to which the data in the right-hand column also relate, refer to species recorded in the following works listed in the Bibliography at the end of this Chapter.

C	Recorded by Crick, G. C., *in* Dibley, G. E., 1918.
Da	Recorded by Dibley, G. E., 1900.
Db	Recorded by Dibley, G. E., 1912.
N	Recorded by Nopcsa, F. von, 1908.
NE	Recorded by Newton, E. T., *in* Dibley, G. E., 1900.
NR	Recorded by Newton, R. B., *in* Dibley, G. E., 1918.
O	Recorded by Owen, R., 1851.
Sh	Recorded by Sherborn, C. D., 1908.
SS	Recorded by Sladen, W. P., and Spencer, W. K., 1891–1908.
Wi	Recorded by Withers, T. H., 1935.
Wo	Recorded by Woods, H., 1899–1913.
Wr	Recorded by Wright, T., 1864–1882.
Ww	Recorded by Woodward, A. S., 1902–1911.
Wx	Recorded by Woodward, A. S., 1905.

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Porifera								
Camerospongia subrotunda (Mantell)	.	.	.	.	x			
Cephalites catenifer T. Smith	.	.	.	x	x			
Plinthosella squamosa Zittel	.	.	.	.	.	x		
Porochonia simplex (T. Smith)	.	.	.	.	x			
Porosphaera globularis (Phillips)	.	.	.	.	x	.	x	
P. patelliformis Hinde	.	.	.	x	x	.	x	
Tremabotites sp.	.	.	.	x				
Ventriculites alcyonoides (Mantell)	.	.	.	.	x			
V. decurrens T. Smith	.	.	.	.	x	.	x	
V. impressus T. Smith	.	.	.	x	.	x		
V. mammillaris T. Smith	.	.	.	.	x			
Anthozoa								
Diblasus gravensis Lonsdale	.	.	.	.	x			
Epiphaxum auloporoides Lonsdale	.	.	.	.	.	.	x	
Onchotrochus serpentinus Duncan	.	.	.	.	.	.	x	
Parasmilia centralis (Mantell)	.	.	.	.	x			
Trochocyathus sp.	.	.	.	.	Db			
Crinoidea								
Bourgueticrinus ellipticus (Miller)	.	.	.	x	x	x		
B. sp.	.	.	.	.	.	.	x	
Isocrinus agassizi (Hagenow)	.	.	.	x	x			
I. kloedeni (Hagenow)	.	.	.	.	x			

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Asteroidea								
Calliderma smithiae (Forbes)	.	SS						pl. i, fig. 1.
Crateraster quinqueloba (Goldfuss)	.	.	.	x	x	x	x	
Metopaster exsculptus Spencer	.	.	.	.	.	.	x	
M. parkinsoni (Forbes)	.	.	.	.	x	x	x	
Stauranderaster sp.	.	.	.	.	.	.	x	
Echinoidea								
Cardiaster pygmaeus Forbes	.	.	x					
Cardiotaxis cf. *ananchytis* (Leske)	.	.	.	.	.	.	x	
'*Cidaris*' *bowerbanki* Forbes	.	x						
'*C.*' *hirudo* Sorignet	.	.	.	.	.	x	x	
'*C.*' *perornata* Forbes	.	.	.	.	x			
'*C.*' *serrifera* Forbes	.	.	.	.	x	.	x	
Conulus albogalerus Leske	.	.	.	.	.	.	x	
C. castanea (Brongniart)	.	.	x					
C. globulus (Desor)	.	.	.	.	.	.	x	
C. raulini (d'Orbigny)	.	.	.	.	.	.	x	
C. subconicus (d'Orbigny)	.	.	.	.	.	.	x	
C. subrotundus Mantell	.	.	x	x				
C. vulgaris (d'Orbigny)	.	.	.	.	.	.	x	
Discoidea cylindrica (Lamarck)	x	.	x					
D. dixoni Forbes	.	.	.	x				
D. subuculus (Leske)	.	x						
Echinocorys scutata Leske	.	.	.	.	x	x	x	
Echinothuria floris S. P. Woodward	.	.	.	.	.	.	Wr	pl. xxxixB, 3, 4.
Epiaster distinctus Agassiz	Da							
Gauthieria radiata (Sorignet)	.	.	.	x	x	x		
G. spatulifera (Forbes)	.	.	.	.	.	.	x	
Hemiaster minimus (Agassiz)	.	.	x					
H. sp.	x							
Holaster subglobosus (Leske)	.	x						
H. trecensis (Leymerie)	.	x						
H. (*Sternotaxis*) *placenta* Agassiz	.	.	.	.	x	x	x	
H. (*S.*) *planus* (Mantell)	.	.	.	x	x			
Micraster coranguinum (Leske)	.	.	.	.	.	.	x	
M. coranguinum var. *latior* Rowe	.	.	.	.	.	.	x	
M. corbovis Forbes	.	.	.	x	x			
M. corbovis, trans. to *M. leskei*	.	.	.	x				
M.cortestudinarium (Goldfuss)	.	.	.	.	.	x		
M. leskei (Desmoulins)	.	.	.	.	x			
M. praecursor Rowe	.	.	.	.	x	x		
M. (*Isomicraster*) *senonensis* Lambert	.	.	.	.	.	.	x	
Phymosoma corollare (Leske)	.	.	.	.	x			

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Echinoidea—*contd.*								
'Plegiocidaris' dissimilis (Forbes)	x							
Stereocidaris sceptrifera (Mantell)	.	.	.	.	x	x	x	
Tetragramma brongniarti (Agassiz)	.	x						
Tylocidaris clavigera (Koenig)	.	.	.	.	x	x	x	
Annelida								
Serpula ampullacea J. de C. Sowerby	.	.	.	.	x			
S. antiquata J. de C. Sowerby	x							
S. fluctuata J. de C. Sowerby	.	.	.	.	x			
S. ilium J. de C. Sowerby	.	.	.	.	x			
'Terebella' cancellata Bather	x							
'T'. lewesiensis W. Davies	x							
Brachiopoda								
Concinnithyris burhamensis Sahni	x	x						
C. protobesa Sahni	.	.	.	x				
C. subundata (J. Sowerby)	x	x						
Crania egnabergensis Retzius	.	.	.	.	.	.	x	
Kingena lima (Defrance)	x	x						
Gibbithyris cordata Sahni	.	.	.	.	x			
G. ellipsoidalis Sahni	.	.	.	.	x	.	x	
G. gibba Sahni	.	.	.	.	.	.	x	
G. merensis Sahni	.	.	.	.	x	x		
G. pyramidalis Sahni	.	.	.	.	.	.	x	
G. semiglobosa (J. Sowerby)	.	.	.	.	x	x	x	
G. subrotunda (J. Sowerby)	.	.	.	.	x	x	x	
Ornatothyris sp.	x							
'Rhynchonella' cuvieri d'Orbigny	.	.	x					
'Rh.' cf. *limbata* (Schlotheim)	.	.	.	.	Db	x		
'Rh.' mantelliana (J. de C. Sowerby)	x	x						
'Rh.' martini Mantell	x							
'Rh.' cf. *plicatilis* J. de C. Sowerby	.	.	.	.	x			
'Rh.' reedensis Etheridge	.	.	.	.	x			
'Terebratula' squamosa Mantell	x							
Terebratulina lata Etheridge	.	.	.	x				
T. nodulosa Etheridge	x	x						
T. striata auctt. angl. *non* Wahlenberg	.	.	.	.	.	.	x	
T. triangularis Etheridge	x							
Thecidea wetherellii Morris	.	.	.	.	.	.	x	
Lamellibranchia								
Astarte sp.	.	.	.	.	x			
Aucellina gryphaeoides (J. de C. Sowerby)	x							

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Lamellibranchia—*contd.*								
Barbatia cf. *geinitzi* (Reuss)	.	.	.	.	x			
Camptonectes dubrisiensis (Woods)	Wo							
Cardita cancellata Woods	.	.	.	.	x			
C. cf. *tenuicosta* (J. de C. Sowerby)	x							
Cardium cenomanense d'Orbigny	.	.	.	.	x			
C. turoniense Woods	.	.	.	.	x			
Chlamys cretosa (Defrance)	.	.	.	.	x	.	x	
Ch. fissicosta (Etheridge)	Wo							
Ch. (*Aequipecten*) *beaveri* (J. Sowerby)	Wo	x						
Ch. (*Ae.*) *pexatus* (Woods)	.	.	.	.	x			
Corbis morisoni Woods	.	.	.	.	x			
Cuspidaria caudata (Nilsson)	.	.	.	.	x			
Cyprina ? sp.	.	.	.	.	x			
Dimyodon nilssoni (Hagenow)	.	.	.	.	x	Wo	x	
Durania mortoni (Mantell)	.	.	Da					1900
Entolium orbiculare (J. Sowerby)	x	x						
Grammatodon carinatus (J. Sowerby)	x							
Inoceramus cordiformis J. de C. Sowerby	.	.	.	.	.	.	x	
I. costellatus Woods	.	.	.	.	x			
I. crippsi Mantell	x	x						
I. crippsi var. *reachensis* Etheridge	Wo	Wo						pl. xlviii, 4–5, xlix, 1.
I. etheridgei Woods	x							
I. inconstans Woods	.	.	.	x	x	x	x	
I. labiatus (Schlotheim)	.	.	x					
I. labiatus var. *latus* J. de C. Sowerby	.	.	.	.	x			
I. lamarcki Parkinson	.	.	.	x	x	x		
I. lamarcki var. *apicalis* Woods	.	.	.	x	x			
I. lamarcki var. *cuvieri* J. de C. Sowerby	.	.	.	x	x	.	x	
I. pictus J. de C. Sowerby	x	x						
I. tenuis Mantell	x							
Lima aspera Mantell	x							
L. (*Ctenoides*) *divaricata* Dujardin	.	.	.	Wo				
L. (*Plagiostoma*) *cretacea* Woods	.	.	.	.	.	Wo		pl. v, 2.
L. (*P.*) *cretacea* var. ?	.	.	.	.	Wo			pl. v, 5.
L. (*P.*) *globosa* (J. de C. Sowerby)	x	x						
L. (*P.*) *hoperi* Mantell	.	.	.	.	Wo	Wo	x	
Limatula wintonensis Woods	.	.	.	.	.	x		
L. sp.	.	.	.	.	x			
Martesia ? rotunda (J. de C. Sowerby)	.	.	.	.	x			

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Lamellibranchia—*contd.*								
Nuculana semilunaris (v. Buch)	.	.	.	.	x			
Ostrea boucheroni Coquand	.	.	.	.	.	.	x	
O. canaliculata (J. Sowerby)	.	.	.	.	x	x	x	
O. incurva Nilsson	.	.	.	.	.	.	x	
O. semiplana J. de C. Sowerby	.	.	.	.	x	x		
O. vesicularis Lamarck	x	x	.	.	x			
Pholadomya decussata (Mantell)	x	x						
Plicatula barroisi Peron	.	.	.	x	x			
Septifer lineatus (J. de C. Sowerby)	.	.	.	.	x	.	x	
Spondylus dutempleanus (d'Orbigny)	.	.	.	.	x			
S. latus (J. Sowerby)	.	.	.	.	x	x	x	
S. spinosus (J. Sowerby)	.	.	.	x	x	x	x	
Trapezium trapezoidale (Roemer)	.	.	.	.	x			
Turnus ? amphisboena (Goldfuss)	.	Wo	.	.	x			
Gastropoda								
'*Aporrhais*' *stenopterus* Goldfuss	x							
Avellana sp., cf. *humboldti* (Müller)	.	.	.	.	Db			
A ? sp.	.	.	.	.	x			
Cerithium cf. *cuckhamsliense* Woods	.	.	.	.	x			
C. saundersi Woods	.	.	.	.	x			
Dentalium turoniense Woods	.	.	.	.	x			
Gyrodes genti (J. Sowerby)	.	.	.	NR				pl. x, fig. 3; text-figs. 1, 3.
Hipponyx dibleyi Sherborn	.	.	.	Sh				
Lampusia sp.	.	.	.	.	Db			
Pleurotomaria perspectiva (Mantell)	.	.	.	.	x			
Solariella gemmata (J. de C. Sowerby)	.	.	.	.	x			
Trochus berocscirensis Woods	.	.	.	.	x			
T. schlueteri Woods	.	.	.	.	Db			
Turbo geinitzi Woods	.	.	.	.	Db			
Turritella dibleyi R. B. Newton	NR							pl. x, figs. 1–2.
Cephalopoda (Nautiloidea)								
Nautilus sp. juv. (*? elegans* J. Sowerby)	C							pl. ix, fig. B.
Cephalopoda (Ammonoidea)								
Acanthoceras cf. *cenomanense* (d'Archiac) trans. to *A. hunteri* Kossmat	.	x						
A. flexuosum Crick	.	x						
A. hippocastanum (J. de C. Sowerby)	.	x						

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Cephalopoda (Ammonoidea)—*contd.*								
A. rhotomagense (Brongniart)	.	x						
A. subflexuosum Spath	.	x						
A. cf. *sussexense* (Mantell)	.	x						
Acompsoceras aff. *bochumense* (Schlueter)	x							
Anisoceras? simplex (d'Orbigny)	x							
Forbesiceras complanatum (Mantell)	x							
Glyptoxoceras sp.	.	.	.	.	Db			as *Hamites? sp.*
Hyphantoceras reussianum (d'Orbigny)	.	.	.	.	x			
H. woodsi (Kitchin)	.	.	.	.	x			
Hyphoplites crassofalcatus (Semenow)	x							
H. falcatus (Mantell)	x							
H. pseudofalcatus (Semenow)	x							
Lewesiceras aff. *sharpei* (Spath)	.	.	.	.	x			
Mantelliceras costatum (Mantell)	x							
Metaptychoceras smithi (Woods)	.	.	.	.	x			
Metoicoceras pontieri (Leriche)	.	x						Belemnite Marls
Protacanthoceras sp.	x							
Prionocyclus neptuni (Geinitz)	.	.	.	.	x			
Puzosia (Austiniceras) sp.	.	x						
Scaphites geinitzi d'Orbigny	.	.	.	.	x			
S. obliquus J. Sowerby	x							
Schloenbachia coupei (Brongniart) (*sic*)	C							pl. ix, fig. A.
S. glabra Spath	x							
S. intermedia (Mantell)	x							
S. cf. *nodulosa* (Stieler)	x							
S. aff. *sharpei* (Semenow)	x							
S. subtuberculata (Sharpe)	x							
S. subvarians Spath	x							
S. tuberculata (Mantell)	x							
S. varians (J. Sowerby)	x							
Sciponoceras baculoide (Mantell)	.	.	.	.	x			
S. cf. *obliquatum* (J. Sowerby)	x							
Turrilites costatus Lamarck	x							
T. scheuchzerianus Bosc	x							
T. tuberculatus Bosc	x							
T. wiesti Sharpe	x							
Cephalopoda (Belemnoidea)								
Actinocamax merceyi (Mayer-Eymar)	.	.	.	.	.	.	Da	

Species	Zone							Recorded or figured
	Schloenbachia varians	*Holaster subglobosus*	*Inoceramus labiatus*	*Terebratulina lata*	*Holaster planus*	*Micraster cortestudinarium*	*Micraster coranguinum*	
Cephalopoda (Belemnoidea)—*contd.*								
Actinocamax plenus (Blainville)	.	x						Belemnite Marls
A. verus (Miller)	.	.	.	.	.	.	Da	
A. westfalicus (Schlueter)	.	.	.	.	.	.	Da	one specimen only
Crustacea (Malacostraca)								
Enoploclytia dixoni (Bell)	x	x						
Crustacea (Cirripedia)								
Calantica (*Titanolepas*) *tuberculata* (Darwin)	Wi							
Cretiscalpellum glabrum (Roemer)	x	.	.	Wi	Wi			
C. glabrum var. *robustum* Withers	.	.	.	.	Wi			
C. glabrum var. *billaulti* Peron	.	.	.	.	.	Wi		
C. striatum (Darwin)	Wi							
Scalpellum (*Arcoscalpellum*) *angustatum* (Geinitz)	Wi	.	.	.	Wi			p. xxv, fig. 17.
S. (*A.*) *lineatum* Darwin	Wi							
S. (*S.*) *trilineatum* Darwin	Wi							
Smilium ? parvulum (Withers)	Wi							
Stramentum pulchellum (G. B. Sowerby)	.	.	Wi					pl. xli, figs. 1-4, pl. xlii, fig. 1.
Zeugmatolepas mockleri Withers	Wi							
Pisces								
Anomaeodus angustus (Agassiz)	.	.	.	.	.	Ww		
Apateodus striatus A. S. Woodward	.	Ww	Ww	Ww				pl. xi, 5, 6.
Aulolepis typus Agassiz	.	Ww						
Belonostomus cinctus Agassiz	.	Ww						
Berycopsis elegans Dixon	.	Ww	.	Ww	Ww			pl. i, 2; ii, 1; liii, 1.
B. major A. S. Woodward	.	.	.	.	Ww			pl. ii, 2.
Cantioscyllium decipiens A. S. W.	.	Ww						pl. xlii, 7-11.
Cimolichthys lewesiensis Leidy	.	Ww	Ww	Ww				pl. ix, 10, 11, 13; pl. xii, 4.
Coelodus fimbriatus A. S. Woodward	.	Ww						
Corax falcatus Agassiz	.	Ww						
Ctenothrissa microcephala (Ag.)	.	Ww						pl. xix, 1.
C. radians (Agassiz)	.	Ww						pl. xvii, 3; pl. xviii, 7.
Edaphodon agassizi (Buckland)	.	Ww						
E. mantelli (Buckland)	.	Ww						

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Pisces—*contd.*								
Edaphodon sp.	.	Ww						pl. xli, 3-4.
Elasmodectes willetti E. T. Newton	.	Ww						pl. xl, 2-3.
Elopopsis crassus (Dixon)	.	.	Ww					
Enchelurus anglicus A. S. Woodward	.	Ww						
Enchodus lewesiensis (Mantell)	.	Ww						pl. xiv, 11.
E. pulchellus A. S. Woodward	.	Ww	Ww	Ww				
Gyrodus ? cretaceus Agassiz	.	.	.	Ww				pl. liv, 5.
Halec eupterygius (Dixon)	.	Ww						pl. xiii, 3, 4, 8.
Holopteryx lewesiensis (Mantell)	.	Ww	Ww	Ww				pl. iii, 2-3; vii, 1.
H. simus A. S. Woodward	.	Ww						
H. superbus A. S. Woodward	.	.	Ww					pl. vii, 2.
H. dorsalis Dixon	.	Ww						pl. vii, 6.
H. rotundus A. S. Woodward	.	Ww						
Ichthyodectes elegans E. T. Newton	.	Ww						
I. minor (Egerton)	.	Ww						
I. tenuidens A. S. Woodward	.	Ww						pl. xxi, 7.
I. sp.	.	Ww						pl. xix, 5.
Ischyodus thurmanni Pictet and Campiche	.	Ww						pl. xl, 7.
I. ? incisus E. T. Newton	.	Ww						pl. xli, 6-7.
Isurus angustidens (Reuss)	.	Ww						pl. xliii, 16, 17.
I. mantelli (Agassiz)	.	Ww						
Lamna appendiculata Agassiz	.	Ww						
Lamna spp. (teeth)	x							
Macropoma mantelli Agassiz	.	Ww	Ww	.	Ww			
M. praecursor A. S. Woodward	.	Ww						pl. xxxix, 3.
M. sp. (coprolites)	x							
Neorhombolepis excelsus A. S. W.	.	Ww						pl. xxxiv, 1.
N. ? punctatus A. S. Woodward	.	Ww						pl. xxxiv, 2.
Notidanus microdon Agassiz	Ww	Ww			Ww			
Osmeroides latifrons A. S. Woodward	.	Ww						pl. xxiv, 1-3.
O. levis A. S. Woodward	.	Ww						pl. xxiii, 9-10.
O. lewesiensis (Mantell)	.	.	.	.	Ww			
Pachyrhizodus ? magnus A. S. Woodward	.	.	Ww					pl. xxviii, 4.
Pachyrhynchus basalis Dixon	.	Ww						
P. dibleyi A. S. Woodward	.	Ww						pl. xxvi, 1.
P. gardneri (Mason)	.	Ww						pl. xxv, 3, 4, 8.
P. subulidens (Owen)	.	Ww						pl. xxvii, 3*a*.
Plethodus expansus Dixon	.	Ww	.	Ww				pl. xxii, 4.
P. oblongus Dixon	.	Ww						
P. pentagon A. S. Woodward	.	Ww						pl. xxii, 6.
Portheus mantelli E. T. Newton	.	Ww	Ww					

Species	Zone							Recorded or figured
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Pisces—*contd.*								
Protosphyraena ferox Leidy	.	Ww						pl. xxxi, 1-5, 7.
P. minor Agassiz	.	Ww						pl. xxxiii, 1-2.
Ptychodus decurrens Agassiz	.	Ww						pl. li, 8-13; lii, 7-15.
P. latissimus Agassiz	.	.	.	Ww	Ww			pl. 1, 6-8, 13-16.
P. mammillaris Agassiz	.	.	Ww	Ww				
P. polygyrus Agassiz	.	.	.	Ww				
P. polygyrus var. *marginalis* Ag.	.	.	.	Ww				pl. xlvii, 13-14.
P. rugosus Dixon	.	.	.	.	.	x		
Sardinioides illustrans A. S. Woodward	.	Ww						
Scapanorhynchus rhaphiodon (Ag.)	.	Ww						pl. xliv, 18-20.
S. subulatus (Agassiz)	.	Ww						
Scyllium antiquum (Agassiz)	.	Ww						pl. xlii, 1-4.
Syllaemus anglicus (Dixon)	.	Ww	.	.	Ww			pl. xx, 1; xxi, 2, 3, 4, 6.
Synechodus dubrisiensis (Mackie)	.	Ww						pl. xlvi, 2.
S. nitidus A. S. Woodward	.	Ww						pl. xlvi, 3-4.
Tomognathus mordax Dixon	.	Ww						pl. xxix, 3.
?parasphenoid dentition of Elopid or Albuline fish	.	Ww						pl. liv, 3.
Reptilia								
Cimoliochelys benstedi (Mantell)	.	O						1851, pls. i-iii.
Coniasaurus crassidens Owen	.	N						pl. iii, 5-6.
Mosasaurus gracilis Owen	.	.	.	Wx				
Rhynchocephalian jaw	.	.	NE					

C. *The following fossils recorded from the Chalk of this area cannot be assigned to particular zones.*

Plantae

Carpolithus smithiae Mantell. Figured, Mantell 1846, pl. ii, figs. 3*a-d*. Lower Chalk.

Porifera

Bensted, 1862, p. 295, states that . . . 'Mr. Toulmin Smith obtained many of his beautiful specimens of Ventriculites' from the Burham pits. This suggests that the specimens came from the Middle Chalk, since *Ventriculites* is not known from the Lower Chalk, and only the base of the Upper Chalk occurs near Burham. There is, however, no original information to confirm the suggestion, either in Smith's published work (1847, 1848) or with his collection in the British Museum (Natural History).

Asteroidea

Stauranderaster [*Pentaceros*] *coronatus* (Forbes) is recorded by Sladen and Spencer 1891–1908, p. 83, from the Lower Chalk.

Crustacea (Malacostraca)

Enoploclytia leachi (Mantell) is figured by Woods 1925–1931, pl. xxiv, fig. 4, from the Middle Chalk.

Pisces

The following fishes are recorded by A. S. Woodward as from the Middle Chalk or from the Turonian. Although the Turonian stage includes the Planus Zone of the Upper Chalk, the specimens are more likely to have come from the Middle Chalk.

Ctenothrissa radians (Agassiz) (pl. xvii, fig. 4.)
Halec eupterygius (Dixon).
Lamna sulcata Geinitz.
Leptotrachelus elongatus (Agassiz).
Macropoma mantelli Agassiz.
Protosphyraena compressirostris A. S. Woodward.
P. ferox Leidy.
Scapanorhynchus rhaphiodon (Agassiz).
Syllaemus anglicus (Dixon).

Reptilia

The following are from the Lower Chalk, according to information on labels in the British Museum (Natural History) kindly supplied by Dr. W. E. Swinton.

(Chelonia).

Lytoloma sp. Figured Owen 1851, pl. vi, figs. 1–3.

(Squamata).

Dolichosaurus longicollis Owen. Figured Owen 1842, pl. xxxix, figs. 3–4; *in* Dixon, F. 1850, pl. xxxviii, figs. 1, 2, pl. xxxix, fig. 4; 1851, pl. x, figs. 1–4.

(Pterosauria).

Lonchodectes compressirostris (Owen). Figured Owen 1851, pl. xxvii, fig. 1, pl. xxviii, figs. 8–10, pl. xxx, figs. 5, *5a*, pl. xxxii, fig. 2.

L. giganteus (Bowerbank). Figured Bowerbank 1846, pl. i, fig. 1 ; Owen *in* Dixon 1850, pl. xxxviii, figs. 4–5; 1851, pl. xxxi, figs. 1–6.

Ornithocheirus cuvieri (Bowerbank). Figured Bowerbank 1851, pl. iv; Owen 1851, pl. xxviii, figs. 1–7, pl. xxx, figs. 1–3.

REFERENCES

BENSTED, W. H. 1862. Notes on the Geology of Maidstone. *Geologist*, vol. v, p. 294.

BOWERBANK, J. S. 1846. On a new Species of Pterodactyl found in the Upper Chalk of Kent. *Quart. Journ. Geol. Soc.*, vol. ii, p. 7, pl. i.

—— 1851. On the Pterodactyles of the Chalk Formation. *Proc. Zool. Soc.*, vol. xix, p. 14, pl. iv.

CRICK, G. C. *See* Dibley, G. E. 1918, p. 94, pl. ix.

DEWEY, H. and C. E. N. BROMEHEAD. 1924. The Geology of the Country around Dartford. *Mem. Geol. Surv.*

DIBLEY, G. E. 1900. Zonal Features of the Chalk Pits in the Rochester, Gravesend and Croydon Areas. *Proc. Geol. Assoc.*, vol. xvi, pp. 484–99, including Appendix by E. T. Newton; and Excursion to Strood and Halling. *Proc. Geol. Assoc.*, vol. xvi, p. 532.

—— 1912. Note on the Chalk Rock in North Kent. *Geol. Mag.*, dec. v, vol. ix, p. 372.

—— 1918. Additional Notes on the Chalk of the Medway Valley, Gravesend, West Kent, North-East Surrey, and Grays (Essex). *Proc. Geol. Assoc.*, vol. xxix, pp. 68–105, pls. vii–x, including Appendices by G. C. Crick and R. B. Newton.

DIXON, F. 1850. *The Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex.* London.

LYDEKKER, R. 1888–9. *Catalogue of the Fossil Reptilia and Amphibia in the British Museum* (*Natural History*), Pts. I, III. Brit. Mus. (Nat. Hist.).

MANTELL, G. W. 1841. On the Fossil Remains of Turtles, discovered in the Chalk Formation of the South-East of England. *Phil. Trans. Roy. Soc.*, vol. cxxxii, p. 153, pls. xi, xii.

—— 1844. *The Medals of Creation; or first Lessons in Geology and in the Study of Organic Remains*. 2 vols., London.

—— 1846. Description of some Fossil Fruits from the Chalk Formation of the South-East of England. *Quart. Journ. Geol. Soc.*, vol. ii, p. 51, pl. ii.

NEWTON, E. T. *See* Dibley, G. E. 1900, p. 496.

NEWTON, R. B. *See* Dibley, G. E. 1918, p. 97, pl. x.

NOPCSA, F. VON. 1908. Zur Kenntniss der fossilen Eidechsen. *Beitr. Pal. und Geol. Osterr.-Ung. u.d. Orients*, vol. xxi, p. 33, pl. iii.

OWEN, R. 1842. Description of the Remains of a Bird, Tortoise, and Lizard from the Chalk of Kent. *Trans. Geol. Soc.*, ser. 2, vol. vi, p. 411, pl. xxxix.

—— 1850. *See* Dixon, F. 1850, pl. xxxviii, fig, 4, 5.

—— 1851. Monograph on the Fossil Reptilia of the Cretaceous Formations. Part I. *Palaeont. Soc.*

ROWE, A. W. 1899. An Analysis of the Genus *Micraster*, as determined by rigid zonal collecting from the Zone of *Rhynchonella cuvieri* to that of *Micraster coranguinum*. *Quart. Journ. Geol. Soc.*, vol. lv, p. 494, pls. xxxv-xxxix.

SHERBORN, C. D. 1908. On two new Gasteropods (*Hipponyx blackmorei and H. dibleyi*) from the White Chalk. *Geol. Mag.*, dec. v, vol. v, p. 436.

SLADEN, W. P. and W. K. SPENCER. 1891–1908. A Monograph on the British Fossil Echinodermata from the Cretaceous Formations, vol. ii, the Asteroidea and Ophiuroidea. *Palaeont. Soc.*

SMITH, T. 1847. On the Ventriculidae of the Chalk; including the description of peculiar Characters of Structure observed in their Tissues. *Ann. Mag. Nat. Hist.*, vol. xx, pp. 73–97, 176–191, pls. vii, viii.

—— 1848. On the Ventriculidae of the Chalk; their Classification. *Ann. Mag. Nat. Hist.*, ser. 2, vol. i, pp. 36–48, 203–20, 279–95, 352–72, pls. xiii-xvi.

SOWERBY, G. B., JR. 1843. Description of a new Fossil Cirripede from the Upper Chalk near Rochester. *Ann. Mag. Nat. Hist.*, vol. xii, p. 260.

SPATH, L. F. 1926. On the Zones of the Cenomanian and the Uppermost Albian. *Proc. Geol. Assoc.*, vol. xxxvii, p. 420.

STOPES, M. C. 1913. *Catalogue of the Mesozoic Plants in the Department of Geology, Part V. The Cretaceous Flora, Part I.* Brit. Mus. (Nat. Hist.).

WITHERS, T. H. 1935. *Catalogue of Fossil Cirripedia in the Department of Geology, vol. ii, Cretaceous.* Brit. Mus. (Nat. Hist.).

WOODS, H. 1899–1913. A Monograph of the Cretaceous Lamellibranchia of England. 2 vols. *Palaeont. Soc.*

—— 1925–31. A Monograph of the Fossil Macrurous Crustacea of England. *Palaeont. Soc.*

WOODWARD, A. S. 1902–11. The Fossil Fishes of the English Chalk. *Palaeont. Soc.*

—— 1905. Note on some portions of Mosasaurian Jaws obtained by Mr. G. E. Dibley from the Middle Chalk of Cuxton. *Proc. Geol. Assoc.*, vol. xix, p. 185.

WRIGHT, T. 1864–82. Monograph on the British Fossil Echinodermata from the Cretaceous Formations, vol. i, The Echinoidea. *Palaeont. Soc.*

Chapter VII

EOCENE AND ?PLIOCENE

EOCENE STRATA occupy just under one-third of the land surface within the area and occur mainly north of Watling Street though a few spurs of the main outcrop and some outliers are found to the south. The following formations, in upward sequence, are present: Thanet Beds, Woolwich Beds, Oldhaven Beds, Blackheath Beds, London Clay, Claygate Beds, and the lower part of the Bagshot Beds. This sequence represents alternations of marine and estuarine conditions of deposition. The Thanet Beds in general are overlapped by the Woolwich Beds, although the overlap is not seen in this area, and these in turn are cut down into, and overlapped by, the Blackheath and Oldhaven Beds which in certain areas may even overstep the Thanet Beds. Local variations in lithology and thickness of the Eocene strata below the London Clay are illustrated in Fig. 4.

Marked faunal and lithological differences indicate a great hiatus between the periods of deposition of the Chalk and of the Eocene Beds. The Chalk of the South of England generally was gently folded and partly eroded before the Eocene strata were deposited so that from place to place the latter may rest on different zones of the Upper Chalk, but palaeontological evidence indicates that in the present area the Thanet Beds lie on approximately the same level in the Coranguinum zone of the Chalk. It is possible that the whole of this area was at one time covered by Eocene strata although during the period of their deposition a land surface may have existed only a short distance to the south.

Of the many workers on the Eocene of the London Basin the names of Prestwich, T. McKenny Hughes and Whitaker are outstanding. In 1850 appeared the first of three papers by Prestwich (1850, 1852, 1854) on the subdivision of the beds between the Chalk and the London Clay, the latter then known as the 'Plastic Clay Formation'. He grouped as the 'Basement Bed of the London Clay' those beds now recognized as the Blackheath and Oldhaven Beds and the other two subdivisions proposed were the 'Woolwich and Reading Series' and the 'Thanet Sands'; all three subdivisions were grouped as the 'Lower London Tertiaries'. Whitaker (1866, 1872) gave detailed descriptions of these beds in Kent including those recorded by McKenny Hughes and showed that the then so-called 'Basement Bed of the London Clay' in fact consisted of a separate group of beds which he named 'Oldhaven Beds'. Numerous references to works of these authors are made in the following account.

The Eocene of the Chatham area falls into the Landenian and the lower Ypresian of the European classification and A. Wrigley (1924, p. 245; 1940, p. 230) has recognized five faunal divisions for the London Clay. The deposits tentatively classed as Pliocene comprise gravelly spreads south of Rochester.

J.A.R.

THANET BEDS

The outcrop of the Thanet Beds, usually about half a mile wide, courses W.S.W. from Cooling to south of Shorne, where it becomes somewhat narrower

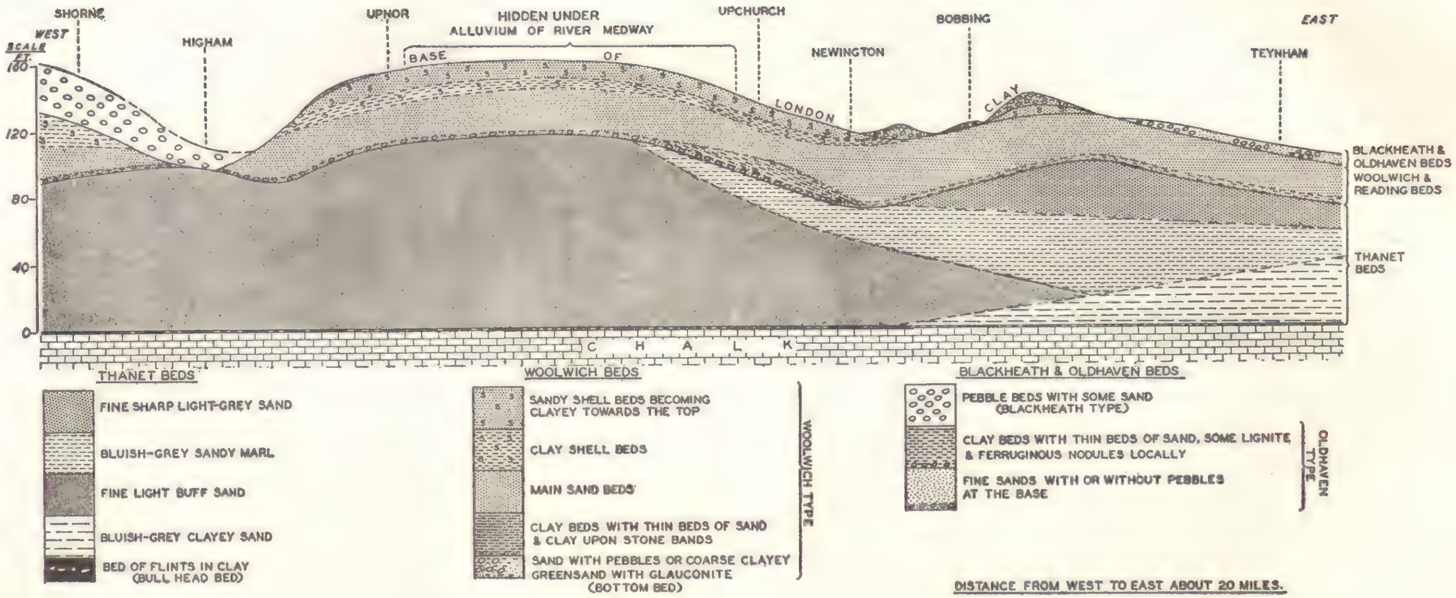

SHORNE
WEST
SCALE FT.
160
120
80
40
0
HIGHAM
UPNOR
HIDDEN UNDER
ALLUVIUM OF RIVER MEDWAY
BASE OF LONDON CLAY
UPCHURCH
NEWINGTON
BOBBING
TEYNHAM
EAST
BLACKHEATH & OLDHAVEN BEDS
WOOLWICH & READING BEDS
THANET BEDS
C H A L K
THANET BEDS
FINE SHARP LIGHT-GREY SAND
BLUISH-GREY SANDY MARL
FINE LIGHT BUFF SAND
BLUISH-GREY CLAYEY SAND
BED OF FLINTS IN CLAY (BULL HEAD BED)
WOOLWICH BEDS
SANDY SHELL BEDS BECOMING CLAYEY TOWARDS THE TOP
CLAY SHELL BEDS
MAIN SAND BEDS
CLAY BEDS WITH THIN BEDS OF SAND & CLAY UPON STONE BANDS
SAND WITH PEBBLES OR COARSE CLAYEY GREENSAND WITH GLAUCONITE (BOTTOM BED)
WOOLWICH TYPE
BLACKHEATH & OLDHAVEN BEDS
PEBBLE BEDS WITH SOME SAND (BLACKHEATH TYPE)
CLAY BEDS WITH THIN BEDS OF SAND, SOME LIGNITE & FERRUGINOUS NODULES LOCALLY
FINE SANDS WITH OR WITHOUT PEBBLES AT THE BASE
OLDHAVEN TYPE
DISTANCE FROM WEST TO EAST ABOUT 20 MILES.

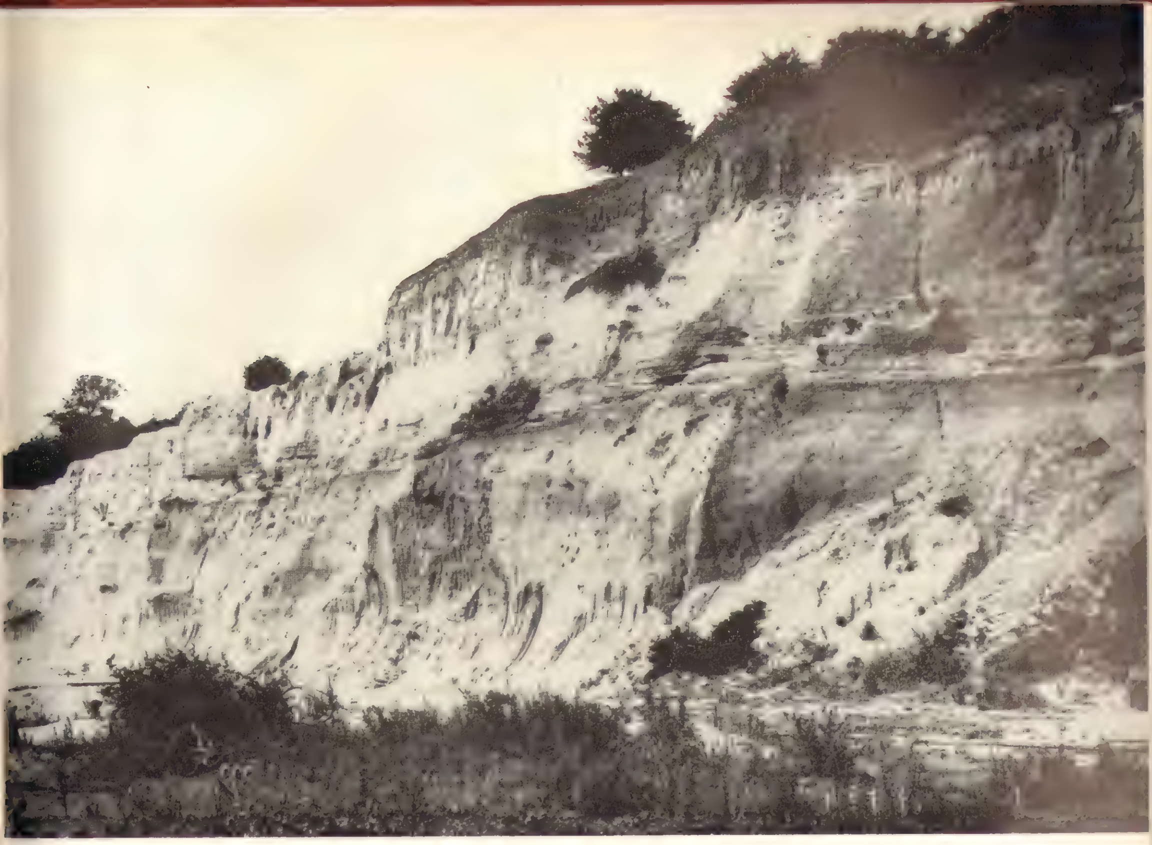
FIG. 4. *Diagram showing depositional variations in lithology and thickness of the Thanet Beds, Woolwich Beds and Blackheath and Oldhaven Beds around Chatham and Sittingbourne*

and swings round to course due east for about 2 miles; it then trends E.S.E. to the Medway at Upnor, at the north end of the Chatham Reach, with two spurs covering the high ground to the south-west, one extending to Shorne and the other from just north of Strood to Great Wood W.S.W. of Rochester. Much of the outcrop is obscured by head (p. 103). There are also several small outliers in this area, notably one at Park Pale. The Thanet Beds continue through Gillingham and Milton to Teynham. Between Otterham Quay, Upchurch, and Newington the outcrop widens to 2 miles, but narrows to about a quarter of a mile a little S. of Bobbing and then gradually widens to almost 1 mile to the N. of Sittingbourne. East of Sittingbourne the outcrop, over 3 miles wide, is much dissected by the dry valleys in the Chalk, the intervening ridges being capped by Thanet Beds. Several outliers are present in the neighbourhood of Rainham and south of Sittingbourne. The base of the formation is irregular as a result of extensive piping into solution hollows in the Chalk. Beneath Higham Marshes and Cliffe Marshes, and in the estuary of the Medway near Gillingham the outcrop is concealed by alluvium.

The Thanet Beds consist mainly of sands (*see* Plate IIIA) though some clay is present especially towards the bottom of the formation and near the eastern limit of the area (Fig. 4). The sand is quartzose with some glauconite, fine and even-grained and where the beds are argillaceous the clay material is more or less evenly distributed through the sand, though it occurs more rarely as small pellets or lumps or as thin beds. The colour varies, being usually grey, greenish grey or buff where no clay is present and blue-grey or greenish with yellow or ochreous mottling in the more clayey beds. A characteristic of the Thanet Beds, presumably due to the fine, even grain and the presence of argillaceous material, is the manner in which for several years a vertical face will remain as if freshly dug. Whitaker proposed five subdivisions for the Thanet Beds in Kent generally, most of which are broadly recognized in the present area. He summarized them in descending order (1872, p. 56), as follows:

> '(*e*) Fine sharp light-grey sand, slightly greenish, often iron-shot, here and there with layers of calcareous sandstone; with fossils, sometimes silicified; thins eastward, and is almost confined to East Kent, where it reaches about 40 ft in thickness, and passes down into—
>
> (*d*) Bluish grey sandy marl, weathering to a pale yellowish grey, often rather hard, with green grains and fossils, more sandy at top; thins westward, and is almost confined to East Kent, where it is the thickest member of the series near and beyond Canterbury.
>
> (*c*) Fine light-buff sand, mostly soft, without fossils (at least but a very few obscure remains have been found); it is thickest in West Kent (up to 60 ft or more), where for the most part it forms nearly the whole of the Thanet Beds, thinning out westward in Surrey, and eastward in Kent.
>
> (*b*) Alternations of brown clay and loam, without fossils, thin and local (to part of East Kent).
>
> (*a*) The "base-bed", clayey greensand, with unworn green-coated flints resting on the Chalk, thin (rarely over 5 ft) but constant.'

The term Bullhead Bed (*see* Plate IIIB) is now generally used for the basement bed and a detailed microscopic investigation of it was made more than sixty years ago by Gardiner (1888, p. 755). Hughes referred to occurrences in this area near Rainham and Moor Street. It is usually about 9 in thick in this area, consisting of dark green-coated flints in dark red-brown, and in places almost black, glauconitic clay with some fairly coarse green sand. The beds of brown clay and loam (*b*) are not present in the area unless the mottled clays

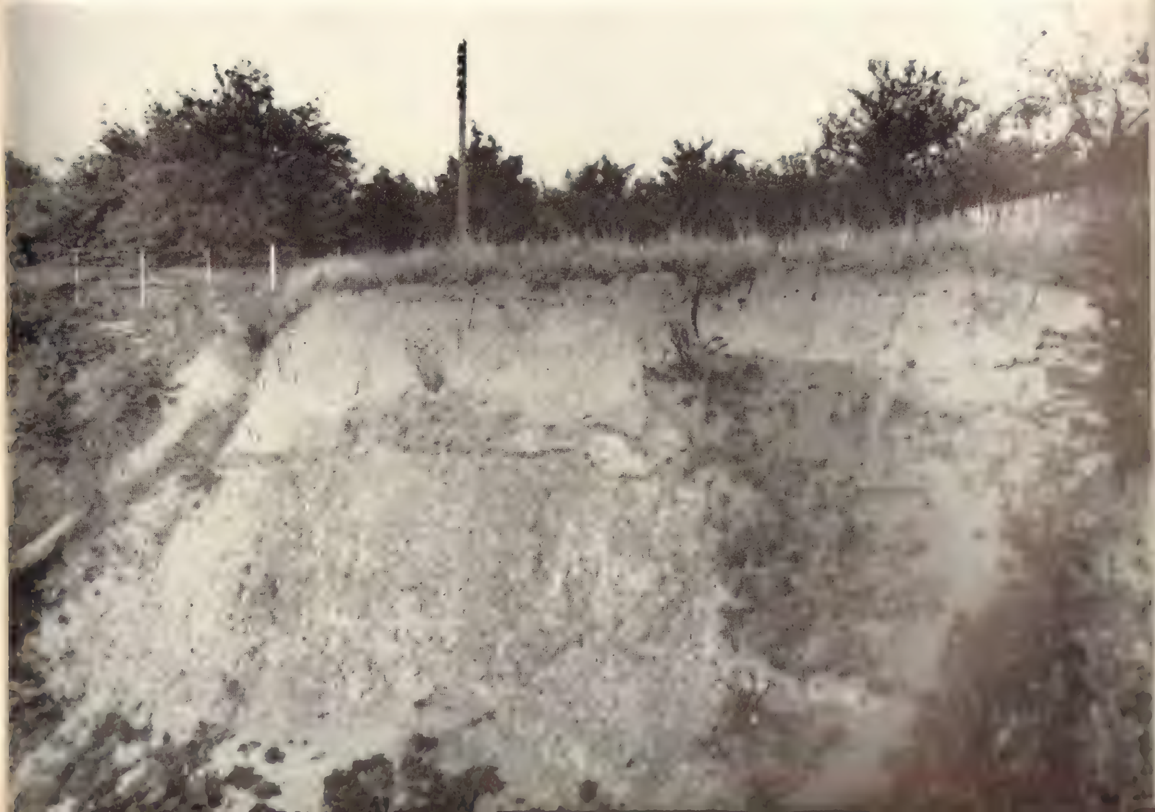


(A 7870)

A. Woolwich Beds and Thanet Sand, Upnor

B. Junction of the Thanet Beds and the Chalk, Mockbeggar, Teynham

(A 7957)



and sandy clays occurring to the south of Scuttington Manor about 2½ miles S.E. of Sittingbourne be included, but they seem to be too high in the sequence. The exact relationship of the other three subdivisions is not always clear; beds (*d*) are seen in numerous exposures east of Sittingbourne but the sand near the bottom of the formation, exposed at the northern end of the outlier 400 yd S.S.E. of Chestnut Street west of Sittingbourne seems more comparable lithologically with group (*e*) than with (*c*). Thanet Beds exposed in several of the brickpits east of Moor Street about a mile east of Rainham might be referred to group (*c*) but the limits of this group are not so clearly defined as the others. Beds of groups (*d*) and (*e*) are well exposed in the road-cutting up the west side of Keycol Hill, Newington. According to Whitaker only beds of group (*c*) are present in the western part of the area although in the pit at Upnor the beds are somewhat clayey. A band of jointed flaggy sandstone near the base of the formation is seen around Higham Upshire at Higham Hall; on Watling Street S.W. of the village; and on the road leading from the village to Shorne and south of Watling Street.

Clay is usually present in the few feet above the Bullhead Bed but in the east the whole of the lower half of the deposit may be argillaceous. This facies has been noted as far west as Thrognall, about 1¼ miles S.S.W. of Newington, where it occupies the bottom 10 ft, and increases in thickness eastwards, till near the limit of the area it is present up to 40 ft from the base. It thins out N.E. of Sittingbourne and is absent north-west of the town.

The Thanet Beds are about 100 ft thick at Murston, about 90 ft north-north-west of, and about 70 ft north-north-east of Green Street. North of Newington the thickness is 70 ft and, south of the village, at Standard Hill, it is somewhat less but the Woolwich Beds present there may be disturbed and out of place. About 2 miles east of Rainham (at Motley Hill) the junction with the Woolwich Beds is seen above the alluvium and the formation has a thickness of about 120 ft. Thicknesses proved in borings were : at Shorne 86 ft and, north of the main outcrop, on the Isle of Grain 91 ft, and at Sheerness 93 ft to 130 ft.

The two beds (*d*) and (*e*) only are fossiliferous and Whitaker has compiled a list of all recorded fossils from these beds in East Kent.

The palaeontology of the Thanet Beds of the present area is discussed below (p. 96).

Spreads of gravel associated with Thanet Beds near Rochester are thought to be possibly of Pliocene age.

J.A.R.

DETAILS

The comparatively wide outcrop of Thanet Beds south of Cliffe and Cooling forms flat or gently undulating country and the soil of fine sandy loam is largely used for market gardening; the only excavation in the formation noted was in the railway-cutting west of Cliffe railway station, which exposed up to 25 ft of fine buff sand. The narrower main outcrop, extending from north of Shorne to Upnor, runs along the foot of the southern slopes of a gentle ridge of ground and the soil is consequently contaminated by hill-wash, giving rise in places to a heavy, cloddy loam with a fairly large content of stones, though elsewhere the normal soil of fine loamy sand occurs, notably south-west of Silver Street and again east of Wainscot, both north of Rochester. A small pit south of Green Farm, 1 mile W.S.W. of Higham railway station, exposes 6 ft of Thanet Sand with the Bullhead Bed, about 1 ft thick, consisting of greenish, yellow-brown clay with green-coated flints, at the base, resting on chalk. The Thanet Beds-Chalk junction is also cut in the railway-cutting near the station, where the apparent dip is 5° N.W. At brickworks south of Beacon Hill, Lower Upnor, described and figured by Whitaker (1872, p. 143) the thickness of Thanet Beds exposed in 1937 was 35 ft. The section showing rather clayey Thanet Beds with Bullhead Bed below, resting on Chalk, also described by Whitaker, was then still exposed at Shorne. The only recent sections worthy of note were those opened up by cuttings on the widened Watling Street and main Strood–Gravesend road which show the normal fine buff sands of the formation, usually overlain by thin washes or small pockets of gravelly material. The occurrence of a band of jointed flaggy sandstone, near the base of the formation in the cutting through Court Wood, Shorne, was recorded by Priest and Epps (1935, p. 61). This sandstone resembles that observed by Whitaker just south of Higham Hall, a quarter of a mile west of Higham Station (1872, p. 73). The fine buff sand of the formation is exposed alongside the lane passing the east side of Court Wood and 120 yd from its junction with the Gravesend road there is saccharoidal sandstone or sarsen that may be in situ. H.G.D.

At Chatham, Thanet Sand was encountered to a maximum thickness of 16 ft beneath drift, in a series of trial holes around the Dockyard; at Cornwall Road, Gillingham, 1100 yd east of the forked roads at Brompton, a section showed 24 ft of pale yellow and buff clayey sand, with the Bullhead Bed at the base; and about 6 ft were noted about 300 yd S.S.E. of this exposure. Sand was also to be seen in the adjacent railway-cutting immediately to the east.
S.B.

The Thanet Beds of the series of outliers between Rainham and Twydall, 1½ miles to the north-west, form only a thin capping on the Chalk. The shallow railway-cutting half a mile N.W. of Cozenton exposed glauconitic buff and grey sand and, in the same spread, up to 5 ft of glauconitic sand and clayey loam, weathering to a brickearth, were formerly dug about 300 yd S.S.E. of Bloors Place. Hughes mentions the outliers at Rainham village and refers to disturbed Thanet material in pipes near Rainham Mark, where, however, there is no continuous spread. S.C.A.H.

Many small exposures occur along the outcrop which extends from the alluvium at Otterham Quay, W.S.W. of Upchurch to Lower Halstow and along that immediately east of Newington, to Keycol. Much of the formerly extensive Brickearth deposit has been dug off; while in some cases this has exposed the Thanet Beds, the floors of many of the pits are today obscured. In the chalk pit (Vineyard Pit), 500 yd north of Moor Street, up to 18 ft of fine-grained greenish grey sand with some buff mottling are to be seen. The sand is a little clayey in parts especially near the Bullhead Bed which consists of the normal green-coated flints in a dark red-brown glauconitic clay, and averages about 9 inches in thickness resting on a somewhat uneven surface of the Chalk. Greenish yellow sand and fine-grained grey laminated sand are seen in the railway-cutting south of Gore House (*see also* p. 85). In the bottom of the brick pit 400 yd south-east of Breach the basal bed of the Woolwich Beds, here a lenticular bed up to 2 ft thick of ferruginous sand with pebbles, rests on 9 ft of fine-grained greenish grey sand of Thanet age. At Lower Halstow, 550 yd west of the school, a temporary pit exposed 1 ft of Made Ground on 5 ft of Brickearth which rest on 5 ft of fine-grained yellowish green sand. The Chalk was proved to be 40 ft below surface in boreholes at the water-cress beds north of Newington and grey sand is exposed in the railway-cutting 150 yd west of the station. Watling Street west of Keycol, is cut into greenish sand with some yellow mottling which passes upwards into grey sand towards the top of the formation at Keycol.

Around Hartlip, the sand is clayey in parts, and as far as Thrognall much of the solid is hidden by Brickearth. A lane-cutting and small pit 350 yd south-south-west of Sweepstakes Farm provide sections in the more southerly of the two small outliers on the east side of the Hartlip Valley southwards from the village. Hughes suggested these outliers are preserved in solution pipes in the Chalk. Here some 10 ft of grey glauconitic loam and sand with yellow streaks rest on 6 in to 1 ft of green-coated large irregular and small rounded flints in tenuous dark greenish brown clayey loam which in turn rests on soft white chalk. Basal Thanet Beds were also seen associated with drift, in the lane-cutting 200 yd west of Sweepstakes Farm, the material being fine-grained. Greenish grey sand was noted about three-quarters of a mile north-east of Stockbury and again 400 yd E.S.E. of Chestnut Street. In the outlier at Borden a large pit 700 yd north-east of the church exposes Thanet Beds from about 1 ft to 15 ft in thickness although the Bullhead Bed often continues where Brickearth cuts out the sand. The sand of the Thanet Beds is generally blue-grey in colour and may be mottled yellow and somewhat clayey towards the base; the Bullhead Bed rests on an uneven Chalk surface. Under the Clay-with-flints at Grove End, half a mile S.S.W. of Tunstall, is a small area of Thanet Beds which appears to be partly disturbed. About 150 yd south of Tunstall Church is a very small outlier of Thanet Beds, and another at Key Street appears to be more in the nature of a large pipe. The section described by Hughes is now completely obscured.

On the main outcrop sand has been dug for brickmaking on the east side of the High Street, Milton, and in one pit-face loam with pockets of gravel rests on 4 ft of fine sand with clayey sand below.

North and west of Bapchild the surface of the Thanet Beds has been much disturbed by the removal of the overlying Brickearth. East of the hamlet of Murston a pit-face, northward of Mere Court, exposed a thin sandy wash and 1 ft of subangular gravel overlying 13 ft of grey sand, clayey towards the bottom of the pit. In the railway-cutting to the south the sand is clayey in parts. A temporary pit 400 yd N.E. of Chilton, south of Sittingbourne, exposed 4 ft of grey sand, not very argillaceous, resting on chalk, and a large brickpit S.W. of Haywood, E.S.E. of Bapchild, has been dug partly in Brickearth and partly in Thanet Beds, the two formations being almost indistinguishable in some sections; pits have been dug in a fine-grained grey sand 1100 yd W.N.W. of Rodmersham.

South and east of the Bapchild district the amount of clay in the lower part of the Thanet Beds shows a marked increase over that of the more westerly outcrop and south-west of Rodmersham the lowest 40 ft or so are definitely clayey. In the more easterly of the two outliers at Woodstock a temporary section, about 40 ft above the base of the formation, exposed clayey blue-grey sand weathering a buff colour. A maximum of about 35 ft of Thanet Beds now remains south of Rodmersham Green and in the neighbourhood of Upper Rodmersham and Scuttington Manor. The whole of the formation there present is a clayey sand, with glauconite occurring in the bottom few feet where red, ochreous and grey mottled clays and sandy clays predominate with, rarely, ferruginous sand.

Exposures are few south of Teynham (=Green Street of older maps) but a chalk-pit 500 yd W.N.W. of Tickham shows pipes of Thanet sand up to 15 ft deep in the Chalk with the Bullhead Bed lining the pipe margins.

A hill which rises from the alluvium to a height of 50 ft O.D., about 1¼ miles N.W. of Teynham, is composed of sand, clayey in the lowest third and with a thin capping of Woolwich Beds, but near Teynham Street, about 1½ miles north-east of Teynham, sand is almost free from clay. East of Teynham about 20 ft of fine grey sand, with an increasing amount of clay towards the base, are exposed in a pit 750 yd south-east of the railway station; the Bullhead Bed rests on an uneven surface of massive chalk. Just west of Deerton Street, argillaceous Thanet Beds, together with the overlying Brickearth, have been dug for brickmaking.

Most of the outlier about three-quarters of a mile S.S.E. of Teynham is concealed by brickearth but according to Whitaker (1872, p. 79) the surface of the Chalk is 40 ft below surface at Newhouse (now Nouds) Farm and much of this thickness must be referable to the Thanet Beds. A pit in chalk S.S.W. of Nouds Farm exposes pipes of sand apparently just on the margin of the outlier.

The main outcrop disappears beneath the alluvium just east of Deerton Street but two sections were noted in the outlier on the extreme eastern margin of the area. The base of the Thanet Beds is seen in the chalk-pit just north of Mockbeggar where 4 ft of fine clayey sand are separated from the Chalk by a 9-in Bullhead Bed. In a cutting on Watling Street, 450 yd east of Norton Ash, about 8 ft of fine clayey greenish blue and buff mottled sand were seen.

J.A.R.

Southward of the mapped outcrops Thanet material occurs scattered over the Chalk tract in many solution pipes and small hollows and to some extent admixed with the Clay-with-flints. Certain larger areas of disturbed Thanet Beds and some smaller piped masses merit brief notice.

South of Chatham, on the high ground between Fort Bridgewoods and the Roman Road, temporary excavations showed Thanet Beds consisting of fine compact loam with clayey bands and some glauconite, seen to a depth of 15 ft and in places probably extending much deeper. Surrounded and overlapped by Clay-with-flints, the loam nevertheless appears to form two main spreads, oval in shape, respectively about 400 yd and 200 yd in long diameter. The beds evidently occupy large solution hollows; they rest on chalk low in the Coranguinum Zone. A local gentle syncline (p. 47) has also probably contributed to the preservation of these masses.

Whitaker (1872, p. 81) describes large pipes of Thanet Beds 400 yd N.N.E. of the inn at Lidsing ['northern end of Lidsing Green'], in the small wood just south-east of Bredhurst Church, and about a third of a mile west-south-west of Oak Barn, near Hartlip ['north-eastern edge of Yaugher Wood']. Of these examples the first is the most notable, for an irregular mass of disturbed loamy sand seems to measure some 80 yd across. S.C.A.H.

WOOLWICH BEDS

The main outcrop, about three-quarters of a mile wide and rather sinuous, appears from beneath the alluvium about a mile east of Cooling and runs southwards for about 1 mile and then westwards as far as Higham, where it widens to about a mile. From south-east of the village the outcrop, again less than half a mile wide, trends eastwards to the Medway north of Upnor. The formation is present in the Eocene outlier at Shorne as a narrow outcrop surrounding the higher formations; it is only a few feet thick at Higham Upshire, having been almost completely eroded before the deposition of the Blackheath Beds. East of the Medway the formation caps Motley Hill, 2 miles N.N.E. of Rainham, and 1½ miles east crops out from beneath the alluvium west of Wetham Green. It forms the top of the hill south of Upchurch and is partly hidden again by alluvium at Lower Halstow, whence it runs S.S.E. to Keycol Hill and then north-east to Milton Creek north-east of Sittingbourne. It caps the high ground about 1 mile south of Upchurch (Hurst Hill), south of Boxted Farm, about half a mile north-west of Newington (Mill Hill), and Standard Hill south of Newington. East of Milton Creek the lower part is present north of Murston and the whole of the formation appears from beneath alluvium at Tonge, Blacketts, and Conyer, all lying east of Gillingham. Two small outliers cap the hills respectively 1 mile E.N.E. of Tonge and a mile south-west of Teynham.

The formation consists for the most part of current-bedded sands with clays; ironstone is present in the western half of the area either as bands of nodules or as thin beds and there are occasional bands of lignite or carbonaceous matter. There is often a pebble bed at the base. The sands are quartzose, grey to greenish grey or sometimes yellow in colour and, with the exception of the yellow sands near the top, are coarser in grain than those of the Thanet Beds; ochreous mottling is common. The clays are usually a dull buff brown colour and often contain a certain amount of sand; some are rather loamy in texture.

The deposits are current-bedded and consequently lithological changes may be quite abrupt; since few large sections are available, correlation of the several lithological types proves somewhat difficult. East of the longitude of Newington the beds consist mainly of sand while to the west a considerable number of clay beds occur, probably occupying up to about one-third of the total thickness (Fig. 4). Several of the subdivisions proposed by Whitaker for this formation in Kent generally are recognizable in the area. The Bottom Bed consists of about 1 ft to 3 ft of rather coarse green glauconitic clayey sand with blue, blue-grey or ochreous flint pebbles usually up to about 1 inch in diameter but, rarely, they may be somewhat larger. East of Newington pebbles are absent but the Bottom Bed is still traceable by other well-defined characters.

Above this are the main sand beds; rather coarse greenish grey or grey sands sometimes current-bedded. This subdivision has a thickness of about 30 ft at Upnor, reaches its maximum of about 36 ft east of Newington and forms the main bulk of the Woolwich Beds eastwards to Conyer where the total thickness is about 20 ft. Clay is present, sometimes dispersed through the sands as in the neighbourhood of Tonge Corner, or, as north-west of Newington, definite beds may be developed. These clay beds, sometimes shaly, alternate with sands in equal proportion. Doggers occur, being most numerous to the north-west of Newington.

The bed of about 3 in to 18 in of purplish sand recorded by Whitaker from the neighbourhood of Upnor has not been found in the eastern half of the area although it appears again near Canterbury. Some of the doggers at Mill Hill when freshly broken have a faint purplish colour as also has the sand-rock just west of Milton Creek.

Next in the sequence are the clay shell-beds, a series of dark buff-brown clays and sandy clays with *Corbicula*, *Melanopsis* and other estuarine shells. These beds are about 6 ft thick at Upnor and may be somewhat thicker north of Newington; they are recorded from only two localities east of that village, in the railway-cuttings just north of Keycol Hill and at Kemsley Halt, north of Sittingbourne where they are 8 ft thick.

A bed of rather fine-grained sand usually yellow in colour and a few feet thick overlies the clay shell-beds and passes upwards into sands with clay and ferruginous layers. The fine-grained sand is believed to be represented by the sand with shells seen just west of Milton Creek. It is exposed in the railway-cutting at Kemsley Halt and in the neighbourhood of Newington where, along with the argillaceous beds above, it may be up to 10 ft thick increasing to 15 ft in the Upnor district.

The thickness of the Woolwich Beds varies considerably, being 33 ft in the railway-cutting south-west of High Halstow and about 50 ft at New Barn south of Cooling. West of Silver Street, about 2 miles north of Rochester, the beds are only 22 ft thick but increase again to 40 ft at Upnor. On the Gadshill outlier east of Shorne only a few feet have been seen and the beds may be absent in places. Where the beds appear above the alluvium near Upchurch they are only about 30 ft thick but increase to at least 40 ft at Mill Hill and to 50 ft south-west of Hawes Wood. They continue thus to Bobbing where they appear to thin to about 30 ft, probably due to overstep of the Blackheath Beds, and again increase to about 60 ft at Kemsley Halt. Eastwards from Milton Creek they are only about 25 ft thick.

The Bottom Bed and the main sand beds are of marine origin. The shell-beds, towards the top of the formation, are crowded with fossils, amongst the many listed by Whitaker being various species of '*Cyrena*', '*Cerithium*', *Melanopsis* and *Ostrea*. J.A.R.

DETAILS

The varied lithological divisions of the Woolwich Beds are well shown in the area west of High Halstow. In the soil of a newly ploughed field, about one-eighth of a mile N.N.W. of the church, Whitaker noted successive layers of sand, shelly clay and lignite, the last apparently near the base of the formation. In a pit west of the village, near Dalham, about 10 ft of yellow, greenish grey and white, false-bedded, slightly indurated sand are exposed and the railway-cutting 500 yd S.W. of the church, though overgrown, seems to be in similar sand. A little below the pit, black pebbles occur in the soil and yet lower strata are exposed in the banks of the sunk lane, a little west of Dalham, where the following sequence can be made out:

		Ft
Rubbly fragments of limonitic ironstone in greenish white sand	estimated	3
Snuff-coloured, glauconitic loamy sand with small orange and red limonitic concretions	estimated	6
Greenish grey, coarse, false-bedded sand, slightly indurated	estimated	2
Yellow and grey loamy sand with lilac and grey laminated clay partings		4
Lilac clay with specks of glauconite and small, black, flint pebbles	. .	½

	Ft
Bottle-green glauconite sand with black pebbles	½
Bottle-green glauconite sand but without pebbles	1
Yellowish green glauconitic sand with clayey streaks	1
Thanet Beds	–

The railway-cutting a mile west of High Halstow church exposes the following section:

		Ft
London Clay and Basement Bed	Brown clay	2
	Orange coloured clay speckled with glauconite	–
	Wisps of grey clay and ½-in bands of nearly pure glauconite sand	2
Possibly Oldhaven Beds	Fine loamy sand	4
	Loamy sand with small black pebbles	1 to ½
Woolwich Beds	Pale yellowish sand	5
	Laminated, yellow, brown and lilac clay with small irony concretions and containing shells in the eastern part of the cutting	2½
	Yellow and lilac sand, very fine and loamy, with ¼-in layer of vermilion colour at the base	1½
	Pale grey and lilac fine sand, loamy and with lilac clay partings above but sharp and slightly indurated below	6 to 7
	Ochreous, yellow and brown iron-sandstone	2
	Ochreous, yellow, coarse loamy sand with small scattered black flint pebbles, passing down into—	5
	Coarse greenish white loose sand	estimated 10

This represents the full thickness of the Woolwich Beds, for pale yellow sand of the Thanet formation occurs at rail level in the western end of the cutting.

Along the outcrop westwards as far as Higham or Church Street, shells are frequently to be seen in the soil of arable fields. About half a mile south of Cliffe railway station pebbles occur and 100 yd north of the farm there is yellow and orange-coloured clay with layers of shells. These beds Whitaker regarded as belonging to the Oldhaven formation, but they are almost at the middle of the Woolwich Beds. The strata immediately below the London Clay are poorly exposed in the eastern end of the railway-cutting, three-quarters of a mile S.W. of Higham or Church Street. There is a bed of shelly clay a few feet below the junction and, some yards farther east, loamy sand with scattered shells. Shelly clay also occurs near the canal, half a mile to the east.

The junction with the Thanet Beds is exposed in small road cuttings 350 yd N.E., and again just over a mile E.S.E. of Higham station. In the former, the basal Woolwich Beds consist of glauconitic, loamy sand with limonitic concretions and streaks of grey clay and, in the other cutting, of coarse, brown sand and sandstone on red-brown clay with sand partings and small black pebbles. In the neighbourhood of these sections there is a group of fine, small, almost conical, hillocks along the outcrop for about three-quarters of a mile E.S.E. from near Two Gates House. These are capped by shelly glauconitic sand, in part indurated. Ochreous sandstone is turned up by the plough in fields around Haven Street, about 1½ miles north of Rochester. About half a mile south-east of Ash a small incised stream valley crosses the outcrop, exposing loamy sand with shells 250 yd north-north-west of Islingham Farm (unnamed on the 1-in map). At the junction with the Thanet Beds, close to the farm buildings, the stream enters small swallow holes. An exposure of loose sand with small black pebbles and shells just below the base of the London Clay, about 150 yd north-east of this point may be in Oldhaven Beds.

About 400 yd west of the inn (Old George Inn) at Hoo Common a band of bog iron ore, limonitic and rather granular, ochreous and earthy, occurs a little below the middle of the formation, and was exposed in a temporary trench. Above it there is dark grey and yellow clay with shells and below yellow and white glauconitic sandstone with white clay seams. Just below the ironstone outcrop the surface is strewn with a dense wash of limonitic fragments. The shelly clay band above the irony bed can be traced for about 500 yd south-eastwards, crossing the Rochester–Hoo road about 550 yd south-west of the above-named inn. Below the clay, sections along this road show coarse greenish to white glauconitic sand with here and there traces of brown sandstone, but no ironstone bed was seen.

At the brickworks at Upnor the Woolwich Beds are essentially as described and figured by Whitaker. They consist of about 23 ft of false-bedded glauconitic sand with greenish grey clay seams, overlain by about 5 ft of bedded clay with shells and that by about 10 ft of slightly indurated brownish gritty sand. The total thickness of the formation seen in 1937 was about 40 ft, or 10 ft less than Whitaker's estimate, in part accounted for by a reduction in thickness of the uppermost bed as now exposed from that formerly seen.

South of Shorne the Woolwich Beds outlier is capped by Blackheath pebble beds which form considerable washes on the lower slopes, covering the outcrop of the former. A brickyard section in the small outlier 400 yd north-east of Shorne Church discussed by Whitaker is now obscured. The reservoir of the Higham and Hundred of Hoo Waterworks, excavated in 1933, alongside the lane passing along the east side of Court Wood a mile east of Shorne and 550 yd from the junction with the main Gravesend–Strood road, was in clay with shells to its full depth of 6 ft 4 in (Priest and Epps 1935, p. 63). About 120 yd N.E. of this, a roadside exposure shows 2 ft of pebbly loam wash on 3 ft of black, grey and yellow clay with shells resting on sandy loam; 80 yd farther N.E. a 1-ft bed of irony sandstone crops out and at a further 80 yd, and near the base of the formation, there is glauconitic sand with white clay seams. At Gadshill (or Telegraph Hill) only a thin remnant of the lower part of the Woolwich Beds is present; between the Thanet Beds and the Blackheath Beds, a few feet of grey and yellow clay on the southern slopes of the hill and a few feet of yellow sand with thin streaks of pipe clay on the northern slopes, are exposed in the banks of the lane running northwards across the hill, although Whitaker states that the latter bed is many feet thick. Beneath the pebble beds in a pit at the north end of the Blackheath Beds outlier there is exposed 1 ft to 2 ft of yellow and white sand with small black pebbles averaging about 1 in. The deposits exposed at these three points, differing widely in character, are representative of the Woolwich Beds in the Gadshill neighbourhood.

H.G.D.

Much of the outcrop around Upchurch is hidden by drift. In this area clay is developed irregularly throughout the formation though generally confined to the beds near the top and the base. As seen in an old brick-pit at Wetham Green about 10 ft of grey sand grade up into sandy clay showing faint lines of bedding with occasionally rather indeterminate beds a few inches thick of sandy clay and clayey sand. London Clay occurs at the top and the absence of any pebble bed indicates the Oldhaven Beds to be absent, though it is possible that they may be represented by part of the sandy clays and clayey sands. In the side of the lane 300 yd W. of Upchurch, yellow and grey sand is seen weathering to a carmine colour. The Bottom Bed is seen by the roadside 600 yd east of Otterham Quay, where coarse-grained glauconitic sand with small blue pebbles is exposed, and again half a mile S. of Upchurch (in Oak Lane) where coarse-grained glauconitic sand rests on fine-grained mottled sand. Coarse-grained clayey sand with glauconite is exposed in a track leading N.W. from Gore House, 300 yd from the buildings. About three-quarters of a mile S.S.E. of Upchurch, and 700 yd S.S.W. of Holywell, sand and sand-rock is exposed and in Holywell Lane were several exposures of sand, clayey sand and grey clay.

South and south-east of Upchurch outliers of Woolwich Beds cap high ground near Gillingham, Hurst Hill and Mill Hill. Doggers from the Woolwich Beds are found in the brickearth on the west side of Hurst Hill, which on a fresh face may be purple or chocolate in colour. The following section is compiled from several exposures in the railway-cutting 300 yd south of Gore House:

		Ft
Head	Coarse-grained ochreous and grey mottled sand	4
	Subangular gravel and sand	2 to 3
Woolwich Beds	Brown clay weathering yellow	3
	Coarse-grained ochreous sand and ferruginous sand with pebble gravel	2
Thanet Beds	Greenish yellow sand and grey laminated sand	

This is only the most easterly part of the section as seen by Hughes (*in* Whitaker 1872, p. 160) who recorded it in much greater detail.

Exposures in the outlier three-quarters of a mile N.W. of Newington (Mill Hill outlier) are few, but a general sequence estimated from the small exposures in the brick-pit 450 yd S.E. of Breach is:

		Ft
Head	Brickearth varying considerably in texture and lithology	1½ to 4
Woolwich Beds	Band of ferruginous mudstone nodules containing quartz grains and crowded with plant remains	up to ¾
	Laminated sands loamy in parts	seen 2
	Dark brown shaly clay interbedded with sand	about 3
	Lenticular bed of ferruginous sand with pebbles	up to 2
Thanet Beds	Fine-grained greenish grey sand	9

In the north face of the pit the head contains many shells and is obviously mainly disturbed Woolwich Beds.

Above this are some 20 ft of Woolwich sand which on top of the hill become clayey and in places alternate with thin clay bands. Pebbles are absent.

Around Lower Halstow sandy clay with shells was ploughed up in a field 350 yd S. of the school. In a brick-pit on the west side of Hawes Wood a little over a mile south of the village, 5 ft of London Clay rest directly on yellow sand with shells, recognized forms being *Corbicula cordata* (Morris), *Brotia inquinata* (Defrance) and *Melanopsis buccinoides* Férussac, with no apparent basal bed. A similar shell-bed is exposed 360 yd N. of Newington Church.

Along the side of the roadway about 150 yd west of Oakhill, three-quarters of a mile N.E. of Newington, mottled clay is exposed and sand is markedly developed between this point and the railway to the south. This sand constitutes about three-quarters of the total thickness of the Woolwich Beds of some 50 ft, and is clean and sharp, of medium grain, and white, greenish grey or yellow in colour.

In the railway-cutting 500 yd S. of Oakhill, the coarse glauconitic sand of the Bottom Bed is exposed, but in the cutting about 300 yd to the east the sequence is much obscured by vegetation and slipped London Clay, although sand and yellow sand-rock are to be seen at rail level. Hughes (*in* Whitaker 1872, p. 154) recorded the following section:

		Ft
London Clay	Chocolate-brown and blue (clay), with much selenite in places, sandy and laminated towards the base, where it is sometimes irregular (as if contorted), with lines of ochreous earth and pieces of wood or patches of lignite	about 25
	At the base sometimes lines of green sand with or without small pebbles; occasionally the base of the clay or the top of the underlying sand has been cemented into a hard stone by iron.	
Oldhaven Beds	Sand with occasional layers of clay and of large pebbles	4 to 6
	At the bottom layers of lignite clay and iron-sandstone..	2 to 4
Woolwich Beds	Yellow iron-stained sand, some beds hardened into a rusty sandstone; finer than the lower sand in the cutting to the west. Nearly horizontal, irregularly cut into by the overlying Series, which scoops into this to a depth of about 15 ft	20 to 25
	Clay shell-bed, touched about 4 ft below the level of the rails in a drain at the western end. Some of it may be seen lying about.	

In the bottom of the cutting at Cold Harbour 1 mile E. of Iwade, now also much degraded, buff sand is to be seen west of the bridge and, 120 yd E. of it, shaly clay (*see also* p. 90).

Standard Hill, just over half a mile S.S.W. of Newington, is capped by a few feet of Woolwich Beds, comprising coarse green sand with glauconite, and which near the base is clayey in parts and contains pebbles.

No exposures occur around Bobbing and between there and Milton Creek the task of drawing the boundary with the Thanet Beds has been rendered difficult by the intensive digging of the brickearth and the consequent destruction of any natural geological features. In the cutting on the Sheerness Railway at Kemsley Halt rather fine-grained yellow sand crowded with friable shells is exposed, but the section has much deteriorated since Hughes recorded the following, quoted from Whitaker (1872, p. 157):

		Ft
London Clay	Clay, generally blue or grey, weathering into chocolate-brown; the lower part sandy, in places with layers of sand, weathering to a brown loam. At the base small black pebbles and very thin irregular beds of clayey green sand with a few teeth of *Lamna*. The junction with the sand below generally sharply defined, sometimes slightly irregular, sometimes quite even; but in one place there appears to be a passage through alternations of sand and clay	seen up to 15

Blackheath and Oldhaven Beds	Sharp grey sand weathering to rusty red. At the base an irregular bed of pebbles (often large) and sometimes about an inch of light-brown clay. In one place a lenticular bed of septarian stone containing casts of *Cardium*, about 3 ft from the base. The Oldhaven Beds rest with a perfectly even but well-defined line upon the Woolwich Beds, and vary in thickness up to	10
Woolwich Beds	Sand full of shells (*Cerithium variabile, Melania inquinata, Melanopsis, Cyrena cordata, C. cuneiformis, C. deperdita ?, Ostrea tenera, Pholadomya*). In one place, at about 8 in from the top, a bed of purple sandstone with casts of shells. Sometimes no shells in the top 8 in or so (which then appears to be resorted), and often this division is more clayey towards the base; contains plant remains	9 to 10
	Blue clay roughly laminated by irregular bits of rusty sand	1½
	Rusty coarse sand, the upper part more red, passing down into the next	1½
	Very clayey yellow sand full of shells, passing down into the next	1½
	Rusty yellow sand, passing down into the next ..	¾
	Bluish grey sharp sand, the lower part very carbonaceous, almost a lignite in places, passing down into the sand below	3
	Fine yellow sand, only just seen at south end of the cutting.	

Some 250 yd W. of Milton Creek and 110 yd S. of cottages at Kemsley is a small exposure where 4 ft of yellow sand rest on 9 in of soft sandstone with beneath a rather fine-grained yellow sand with shells. The absence of any pebbles suggests that these beds belong to the Woolwich rather than to the Oldhaven Beds.

There are no sections in the detached outcrop at Murston but the soil flooring the brickworks is a sand somewhat similar to that seen north of the railway east of Newington.

Between Murston Marshes and Conyer Creek the sand has some clay throughout the formation similar to that north-west of Newington. On the edge of the alluvium about 1 mile N.N.E. of Milton Church, in an overgrown gravel pit, glauconitic sand occurs beneath the gravel; in a brick-pit 450 yd S.S.W. of Tonge Corner 2 ft of sandy loam with pebbles rest on grey sand. At the road branch to Blacketts from that to Tonge Corner coarse glauconitic sand is seen just above fine clayey sand, and 200 yd along the road to Blacketts, coarse clayey sand. Ochreous and grey mottled sand is seen in an overgrown pit on the south side of the road 350 yd S.W. of Blacketts; Hughes recorded the following section from this pit:

	Ft
Rusty loam, roughly laminated	2
Grey, rusty and buff sand with a good deal of clay in places, as shown by moist patches	2
Pinkish buff sand, which becomes a sort of greywether sandstone in places	2
Very light grey sparkling quartzose sand with rusty lines and patches; very incoherent and blows about when dry	2

On the edge of the alluvium, 480 yd E.S.E. of Blacketts, mottled glauconitic sand is exposed.

There are no exposures in the outcrop east of Conyer Creek unless the sand seen under the pebbles in the stream cliff south of the brickworks belongs to the Woolwich Beds. No exposures in the outliers capping the hills respectively three-quarters of a mile E.N.E. of Tonge and just south-west of Teynham Street were noted but the coarse clayey sand, in places glauconitic, of the lower part of the Woolwich Beds, was proved.

BLACKHEATH AND OLDHAVEN BEDS

Blackheath and Oldhaven Beds have only been recognized in the extreme west of the area and eastward of Newington; between Upnor and High Halstow and in the Upchurch-Newington district it is possible that some may be present, but owing to a marked thinning of the formation, the absence of a well-developed pebble-bed and, if these beds are in fact present, the remarkable similarity of their lithology to that of the Woolwich Beds below, it has not been possible to recognize them. An outlier occurs at Shorne and a smaller one at Higham Upshire. The formation crops out sporadically from beneath the London Clay in the neighbourhood of Bobbing, while east of Milton Creek the main outcrop is largely hidden beneath the alluvium, but several small outliers lie to the south.

The Blackheath and Oldhaven Beds comprise current-bedded sands and pebble beds. The sand is mainly quartzose and may contain small fragments of flint; it is usually rather fine-grained, yellow, buff or ferruginous in colour and clayey locally. The pebbles consist almost entirely of flint but a few of pale greyish 'quartzite' also occur, possibly derived from the sarsens of the Woolwich and Reading Beds (Baker 1920, p. 62). The flint pebbles are smooth, generally dark blue or black in colour and, averaging 3 in, may measure up to 8 inches in length. Beds of clay, lignite and ferruginous nodules are developed here and there, notably west of Bobbing.

By general usage the terms 'Blackheath Beds' and 'Oldhaven Beds' have come to mean respectively pebble beds with sands, and the sandy type of beds occurring in East Kent. The transition from one type to the other takes place mainly within the present area (Fig. 4); dense masses of pebbles are rare in the east but predominate in the west. The formation rests on the eroded surface of the Woolwich Beds, into which it cuts deeply at Higham Upshire, although in the eastern part of the area the unconformity is not so evident.

The thickness of the formation varies considerably. In the railway-cutting at High Halstow 5 ft are present. South of Shorne the beds are about 18 ft thick and in the outlier of Gadshill, although the full thickness is not present, 20 ft remain. In the river cliff at Upnor, according to Whitaker, 4 ft to 8 ft can be assigned to this division. At Upchurch even if the sandy-clay and clayey-sand beds actually belong to this formation, the thickness would not be more than 5 ft. East of Lower Halstow there may be about 3 ft of sand and pebbles, and in the railway-cuttings west of Bobbing the thickness varies from 2 ft to 12 ft, and east of Bobbing the beds are up to 5 ft thick. Whitaker records a maximum of 10 ft in the railway-cutting beside Kemsley Halt. North of the outcrop a borehole at Chattenden Barracks penetrated 7½ ft of strata assigned to the Oldhaven Beds and at Allhallows the formation was pierced to a depth of 10 ft without reaching the base. In a borehole on Burntwood Island a thickness of 8 ft was proved and a similar thickness was doubtfully classed as Oldhaven

Beds in a borehole at Queensferry. On the Isle of Sheppey the average thickness is about 17 ft but in a boring at Queenborough 28 ft were proved.

The fauna of the Blackheath and Oldhaven Beds is extensive and, where the formation rests on Woolwich estuarine beds, includes freshwater, estuarine and marine forms of molluscs. A faunal list is given in Chapter VIII below.

J.A.R.

DETAILS

West of the Medway both the Blackheath and the Oldhaven facies are represented, the former being confined to the Shorne and Gadshill outliers and the latter to the area of main outcrop of the Lower London Tertiaries to the north.

The Blackheath Beds near Shorne are largely under woodland. In 1920, C. E. N. Bromehead noted an old pit three-quarters of a mile S.S.W. of Shorne showing 10 ft of current-bedded sand with a few pebbles, another pit on Shorne Common in which 3 ft of pebble bed, in places cemented by limonite, and resting on 14 ft (seen) of fine sand with scattered pebbles and several 1-in ironshot bands were exposed, and a third on the spur, 200 yd north-west of Shorne Church, which showed up to 12 ft of pebble beds.

In the Gadshill outlier, a gravel pit at the northern end exposed, in 1937, 12 ft to 14 ft of densely packed pebbles resting on 1 ft to 2 ft of white sand with scattered small black pebbles, which probably belongs to the Woolwich Beds. Fine, soft, greenish buff sand of the Thanet Beds was exposed in the deeper parts of the pit. The pebbles of the main mass average 1½ in to 2 in, but stones up to 6 inches in length are not uncommon. They are generally grey-brown in colour and exhibit white spots or depressions where desilicification has set in at points of pressure against adjacent pebbles. The matrix, generally sandy, has wavy bands of more clayey material, probably having been contorted under cold conditions. There is a high iron content which has been leached out of the surface layers and deposited below giving rise to a dirty, sooty appearance and locally acting as a cement. The downward leaching of the iron is controlled by the more clayey layers in the matrix and where these have been pierced by plant roots the iron oxide has passed through to lower levels.

In the area west of the Medway, the deposits of Oldhaven facies are thin, seldom exceeding 6 ft. The lithological character of this type, moreover, is very similar to that of the underlying Woolwich Beds, and, though a thin bed of pebbles is frequently found at the base, it is not persistent, and where present is not sufficiently marked to form a stratigraphical line that can be followed with certainty in the field. In this area, therefore, the Oldhaven Beds have not been separated from the Woolwich Beds.

In an excavation, now obscured, at the Kiln (shown on the Old Series Geological Map, Sheet 1 S.E.) east of the road fork just west of High Halstow Church, Whitaker noted 6½ ft of light buff sand with two layers of shells and, below, 6 in of black flint pebbles with an impersistent layer of shells at the top; the fossils confirm the Oldhaven age of these beds. The section exposed in the railway-cutting 1 mile west of High Halstow includes about 4½ ft of strata that can be assigned to the formation. Oldhaven Beds may be present in the railway-cutting a mile north-west of Higham Station, a suite of fossils collected here being suggestive of Oldhaven age (Priest and Epps 1935, p. 63). A small exposure of loose sand with shells and small pebbles, about a quarter of a mile east of The Mount north of Rochester may belong to the Oldhaven Beds. The only other exposure of note in this area is that in the brickworks on the south side of Beacon Hill at Lower Upnor, where Whitaker assigned 4 ft to 8 ft of strata to the formation, but when the section was seen in 1937, only a bed of buff sand with shells, of irregular thickness, averaging 2 ft or less, was visible between Woolwich Beds and London Clay; the latter showed some signs of slipping and may have obscured higher beds. H.G.D.

Hughes (*in* Whitaker 1872, p. 159) tentatively suggests that the deposits seen in the railway-cutting near Gore House, south of Upchurch, may be Oldhaven Beds, completely cutting out the Woolwich Beds, but the section resembles the Woolwich Beds section at Breach (p. 85).

In the track about 150 yd south-east of Bog Farm, north of Newington, a few fairly large pebbles are seen which may have been derived from a local pebble-bed, and more pebbles are to be seen south-east of Oakhill. The railway-cutting, now obscure, about one-third of a mile south of Oakhill, formerly exposed 8 ft of Oldhaven Beds (p. 86). In the railway-cutting at Cold Harbour, west of Bobbing, no section is now to be seen but the description recorded by Hughes shows that west of the bridge London Clay rests on '2 ft to 9 ft of loose buff sand with carbonaceous stains . . . generally more clayey towards the base, where there is a bed (about a foot thick) of very large pebbles' which in turn rests on Woolwich Beds. East of the bridge Hughes saw the following:

		Ft
	Surface soil	1 to 2
Oldhaven Beds	Light buff, fine, sharp sand, dusty when dry, the lowest ½ ft full of pebbles	4 to 5
	Rusty, clayey sand with ferruginous nodules and pebbles in irregular beds. Some of the pebbles large, some small and flat. More clayey towards the base, where there are obscure casts of shells (*Cyrena ?*) and fragments of shell in laminated clay into a thick bed of which the clayey sand passes down	6 to 8
	Light-blue, stiff, grey clay, with little holes, as if rootlets had run through.	
Woolwich Beds	Rusty sand	about 5
	Stiff, blue, laminated clay, with sand, especially towards the middle; this seems to be often accompanied, and sometimes replaced, by lignite or carbonaceous sand	6?
	Sand with a thin bed of black clay, sometimes with beds of red and purple sandstone	[not measured]

At Bobbing pebbles occur in a lens-shaped bed and on the Bobbing–Milton road London Clay apparently rests directly on Woolwich Beds. North-eastwards pebbles occur in red-brown sand beside Upper Toes Farm. In the old sand pit on the west side of the railway at Kemsley Halt, clay rests on sand which Hughes regarded as being Oldhaven Beds.

About 250 yd west of Milton Creek and 200 yd north-east of Castle Rough a small exposure showed 4 ft of yellow sand resting on 9 in of sand-rock succeeded downwards by a rather fine-grained yellow sand with shells which, however, may belong to the Oldhaven Series.

East of Milton Creek the Blackheath type predominates, the outcrop appearing from beneath the alluvium north-west of Blacketts about 2½ miles north-east of Sittingbourne. Sand occurs above the pebble bed and may be clayey or ferruginous. A small isolated outcrop occurs 700 yd north-east of Blacketts where fine yellow or grey and ochreous mottled sands contain pebbles, and sand with pebbles covers the high ground and forms three small outliers south and south-east of Tonge Corner; in a ditch dug in the largest of these, Hughes saw red, brown and buff sand overlying about 3 ft of pebble gravel. A small outlier 250 yd S.S.W. of Blacketts shows brown clayey sand with pebbles.

East of the creek running past Conyer, north of Teynham, the outcrop comprises sand with pebbles some being up to about 4 in long on the longest axis. In the small cliff at the side of the creek 1½ ft of pebble gravel rest on sand. To the south of the main outcrop and 250 yd north of Conyer is a small outlier of pebble gravel. J.A.R.

LONDON CLAY

London Clay occupies the ground surface in three main tracts: an elongated area of about sixteen square miles running north-east from Frindsbury through High Halstow to Allhallows, and an area of about five square miles around Iwade, also partly covered by drift; and the western part of the Isle of Sheppey. The formation, however, also underlies a great part of the alluvium of the Medway estuary and the Swale, and also the Halstow and St. Mary's marshes of the Thames estuary. Rising from the Medway alluvium are a number of 'islands' of London Clay, of which the following are the more important: the Isle of Grain; Elmley; Rushendon, south of Queenborough; Benney, east of Allhallows; and Chetney, north-west of Iwade. In the Sheppey marshes occur many mounds scattered irregularly over and rising from 4 ft to 20 ft above the alluvial plain. They vary from a few feet to 150 ft in diameter. Hughes (*in* Whitaker 1872, p. 291) discusses these in some detail, and concludes that they were formed by tidal action cutting off parts of London Clay which were more resistant to marine action than others, which have subsequently been rounded by sub-aerial action. This may be true of some, but others appear to be the projecting tops of hills of a drowned and now silt-covered topography.

Outliers of London Clay occur about 1½ miles N.N.E., and half a mile south-west of Shorne; a quarter and three-quarter miles N.N.E. of Upchurch; west of Hawes Wood, north of Newington; and as a group of four small patches near Blacketts, 2 miles north of Teynham.

The Frindsbury-Alhallows outcrop forms a comparatively steep east–west ridge rising to above 200 ft O.D. around Chattenden Farm near Frindsbury. Around High Halstow the steep contours of the slopes give rise to landslips, notably at Lodge Hill; west of the village; and again near Northward House (*see* Plate VA). It also occurs south of Chattenden, where undercutting of the soft Lower London Tertiaries by the River Medway may have assisted slipping.

West of a line running north-eastwards from Wainscot, the London Clay outcrop is bare, apart from a scattering of flints and pebbles in the stiff clay soil, but east of the line it is covered by a thin deposit of head, largely derived from the patches of river gravel that occur here. The soil is, therefore, more loamy and stony than that of the bare London Clay and is largely given over to arable and market garden land, in contrast with the essentially pasture-land that occupies the bare outcrop.

The elevation of the Iwade tract generally lies below 100 ft O.D., while the Isle of Sheppey is a little higher.

The great mass of the London Clay consists of a homogeneous clay, inky-blue to slate coloured when fresh, weathering to brown, the colour of most surface exposures. At the base a glauconitic sandy Basement Bed is present, usually not more than 2 ft thick, often less, and including locally a few pebbles, and a very thin band of ferruginous rock. Sections are rare apart from those of the Sheppey cliffs, any exposure being rapidly masked both by slipping and by the growth of vegetation.

In the Sheppey area in particular the formation is highly fossiliferous; its extensive flora has been exhaustively monographed by Mrs. Clement Reid and Miss M. E. Chandler (1933) to whose work reference should be made; the recorded fauna is listed below (p. 99).

Practically the whole of the fossils from Sheppey have been found on the foreshore, washed out of the clay by the sea, and until 1934 it was unknown from which part of the London Clay they were derived; whether from a highly fossiliferous zone below low tide level or, more probably, from the crumbling cliffs. At that date, however, D. J. Jenkins (*see* Edwards 1936) discovered in situ a fossil fruit of *Nipa burtini* (Brongniart) in the cliffs near Minster.

The London Clay is present in full thickness only in the Isle of Sheppey, where Prestwich (1854, p. 401) estimated it to be between 470 ft and 480 ft. With this, however, is included some 20 ft of Claygate Beds, and with that correction Prestwich's estimate conforms in a remarkable degree with a modern estimate of about 450 ft as deduced from more recent evidence from well-borings and other sources. F.H.E.

DETAILS

The Basement Bed was noted in the railway-cutting 1 mile west of High Halstow. A brickworks at Wetham Green, north of Upchurch, exposed up to 4 ft of brown clay resting on a foot or so of dark green sand, representing the Basement Bed. At a brickworks about 1½ miles E.N.E. of Lower Halstow about 10 ft of stiff blue clay, weathering brown with septaria were noted, and on the west side of Hawes Wood, north of Newington, 5 ft of clay rest on the Woolwich Beds, the Basement Bed being absent.

The railway-cutting at Calves Hole described by Whitaker (1872, p. 154) is now so degraded that the base of the London Clay cannot be seen. A slip at the top of the cutting exposes a few feet of contorted shaly clay with selenite; the individual surfaces of the shaly partings have a silvery appearance. The cutting formerly exposed at the base of the London Clay 'sometimes lines of green sand with or without green pebbles; occasionally the base of the clay or top of the underlying sand has been cemented into a hard stone by iron'.

About a third of a mile north-east of Bobbing Church on the road to Milton, sandy clay overlies a bed of ferruginous sandy clay a few inches thick which passes downwards into the sand, the middle bed being the base of the London Clay, and south of Iwade, on the west side of the road to Great Grovehurst, 125 yd north of the road over railway bridge, excavations for house foundations exposed the base of the London Clay developed as a ½-in band of ferruginous rock resting on yellow sand.

The cliffs of Sheppey, nearly 200 ft high at the maximum, are comprised of a confused mass of crumbling and landslipped clay and overlying beds.

The exposed clay is stiff and tenacious, and is weathered to a dark brown colour, and little evidence of undisturbed stratification is to be seen. Large pieces of wood are often to be seen in the mass of the clay. According to Mrs. Reid and Miss Chandler, W. H. Shrubsole, a keen local geologist, concluded that disintegration of the cliffs is produced by the combined action of land springs given out at the base of the Bagshot Beds near the top of the cliff face, on the one hand, and the eroding action of the sea at the foot of the cliffs on the other. H.G.D., S.B., J.A.R.

CLAYGATE BEDS

Present only in the neighbourhood of Minster in Sheppey, these transitional beds between the London Clay and the Bagshot Beds consist of about 12 ft of thin alternating beds of clay and sand, the former often carrying the characteristic lilac colour of the Claygate Beds of the London district.

They crop out as a narrow band surrounding the hill on which Minster is built, and as a second narrow band, intercepted by the sea cliffs, through Mill Hill, Tadwell and Norwood, which is continued into the area of the adjoining 1-in New Series Sheet 273 (Faversham). These beds also floor a small valley running northward to end in the cliffs a little east of East End. Occasional water seepages are thrown out by the sandy beds.

DETAILS

The following section was seen in the cliffs half a mile north of Minster Church (at Merryman's Hill of the 6-in map Kent 13):

		Ft
Claygate Beds	Soil	¾
	Stiff, brown clay	2
	Stiff clay with the seams of fine sand (up to 2 in)	3
	Stiff, brown clay	4
	Fine, yellow, clayey sand with glauconite and mica passing into London Clay	1¼

About 400 yd east of the boundary of the present area, again in the cliffs, the following beds were noted beneath about 7 ft of drift and Bagshot Beds:

		Ft
Claygate Beds	Alternation of mauve-coloured clay and sand	3
	Loam	¾
	Mauve-coloured sand and shale passing into London Clay	8

S.B.

BAGSHOT BEDS

Fine-grained buff sand and flint pebbles are present in two almost contiguous outliers, one supporting the town of Minster, the other immediately to the east. Their presence is indicated by the sandy and pebbly nature of the soil, and their approximate boundaries by a line of small springs; these, however, are not entirely diagnostic, since seepages also arise from the underlying Claygate Beds.

DETAILS

Bagshot Beds, some 15 ft thick, were recorded by T. McKenny Hughes (*see* Whitaker 1872, p. 318) at a section in the cliffs at East End, but the greater part of his section would appear to be in Claygate Beds. A thickness of 10 ft of sand beneath a pebbly wash, overlying Claygate Beds, was noted near the same spot.

The greater part of a local development of a Bagshot Pebble Bed appears now to be incorporated in a head gravel, and no undisturbed section of pebble bed was noted in the cliffs; but a gravel pit about 300 yd east-north-east of Tadwell showed, beneath 3 ft of pebbly brickearth, up to 8 ft of pebble beds with lenses of sand, which may well be part of an original deposit of Bagshot age. S.B.

? PLIOCENE DEPOSITS (OLDER GRAVELS)

In Great Wood, 2¼ miles west by south of Rochester Bridge, an isolated spread of gravel about 440 ft O.D. caps a hill of Thanet Beds, and similar gravel on the hills west of Halling were regarded by Prestwich (1890, p. 157) as belonging to his 'Southern Drift', equivalent in part to his 'Westleton Beds'. S. W. Wooldridge (1927, p. 66), however, regarded it as an off-shore remnant which may be correlated with certain Pliocene deposits that occur at greater heights near the crest of the Chalk escarpment and which he finds to contain the same suite of heavy minerals. The gravel is poorly exposed, but a small pit in the western part of the spread, in 1937, showed 4 ft of pale buff to orange-coloured loam with coarse sand-grains, containing subangular ochreous and white flints, flint cobbles, flint pebbles (probably derived from Eocene formations) and subangular cherts. The deposit, which appears to have suffered disturbance under cold conditions since the stones are arranged irregularly and some set vertically, is regarded as probably of Pliocene age.

It is probable that Pliocene materials are incorporated locally in the Clay-with-flints. While the only sands noted in pipes, which also contain Clay-with-flints, are of Eocene type (Thanet Beds), occurrences of concretionary sandy ironstone in lumps scattered over the high ground about Bluebell Hill, Lidsing and Bredhurst suggest a Pliocene derivation. Fragments of chert and ironstone of Lower Greensand origin and of saccharoidal sarsen stone or quartzite from the Eocene were probably transported mainly during the Pleistocene but some may have been introduced during the Pliocene. H.G.D., S.C.A.H.

REFERENCES

BAKER, H. A. 1920. On the Quartzite Pebbles of the Oldhaven (Blackheath) Beds of the Southern Part of the London Basin. *Geol. Mag.*, vol. lvii, p. 62.

EDWARDS, W. N. 1936. The Flora of the London Clay. *Proc. Geol. Assoc.*, vol. xlvii, p. 22.

GARDINER, M. I. 1888. The Greensand Bed at the Base of the Thanet Sand. *Quart. Journ. Geol. Soc.*, vol. xliv, p. 755.

HUGHES, T. MCK. 1866. Note on the Junction of the Thanet Sand and the Chalk and of the Sandgate Beds and the Kentish Rag. *Quart. Journ. Geol. Soc.*, vol. xxii, p. 402.

—— 1872. *See* Whitaker, W.

PRESTWICH, J. 1850, 1852, 1854. On the Structure of the Strata between the London Clay and the Chalk in the London and Hampshire Tertiary Systems. *Quart. Journ. Geol. Soc.*, vol. vi, p. 252; vol. viii, p. 235; vol. x, p. 75.

—— 1890. On the Relationship of the Westleton Shingle to other Pre-Glacial Drifts in the Thames Basin, and on a Southern Drift. *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 155.

PRIEST, S. and F. J. EPPS. 1935. Field Meeting at Higham and Shorne. *Proc. Geol. Assoc.*, vol. xlvi, p. 63.

REID, E. M. and M. E. J. CHANDLER. 1933. *The London Clay Flora*. Brit. Mus. (Nat. Hist.)

STAMP, L. D. 1920. Geology of the Swanscombe Eocene Outlier, Kent. *Proc. Geol. Assoc.*, vol. xxxi, p. 187.

WHITAKER, W. 1866. On the 'Lower London Tertiaries' of Kent. *Quart. Journ. Geol. Soc.*, vol. xxii, p. 75.

—— 1872. The Geology of the London Basin, Part I. *Mem. Geol. Surv.*, vol. iv. (Includes notes by H. W. Bristow and T. McK. Hughes.)

WOOLDRIDGE, S. W. 1927. The Pliocene History of the London Basin. *Proc. Geol. Assoc.*, vol. xxxviii, p. 49.

WRIGLEY, A. 1924. Faunal Divisions of the London Clay, illustrated by some Exposures near London. *Proc. Geol. Assoc.*, vol. xxxv, p. 245.

—— 1940. The Faunal Succession of the London Clay, illustrated by some Exposures near London. *Proc. Geol. Assoc.*, vol. li, p. 230.

Chapter VIII

PALAEONTOLOGY OF THE EOCENE FORMATIONS

THE following lists of fossils have been compiled from the sources indicated in the references on p. 102.

THANET BEDS

The fauna of the Thanet Beds of the London Basin is richest in the east of Kent (as at Pegwell Bay and Reculver) and dwindles towards the west. In the Chatham area there is already a marked falling off in abundance and variety, though the list is still longer than any that would be compiled with reference to more westerly districts. The single locality, near Sittingbourne, from which fossils are recorded cannot now be accurately fixed.

Locality—near Sittingbourne (? Murston).

Lamellibranchia

- *Nucula sp.*
- *Glycymeris sp.*
- *Ostrea sp.*
- *Cyprina morrisii* J. de C. Sowerby
- *Protocardia sp.*

Gastropoda

- *Aporrhais dispar* (Deshayes)
- *Turritella sp.*

Crustacea

- indeterminable fragments

Pisces

- Sharks' teeth
- *Edaphodon ? leptognathus* Agassiz
- *Albula ? sp. nov.*
- bones, teeth, scales and vertebrae of bony fishes.

WOOLWICH, BLACKHEATH AND OLDHAVEN BEDS

Faunal lists of these beds clearly include fossils from both the marine 'Bottom Bed', or zone of *Cyprina scutellaria*, and from the estuarine shelly clays above. The Blackheath and Oldhaven Beds fauna is substantially that listed by Wrigley (*in* White 1931, p. 111), with the incorporation of other published records. It is predominantly a marine or Oldhaven fauna at High Halstow, but at Upnor, to the south-west, there appear some of the estuarine forms which become increasingly important further westward.

WOOLWICH BEDS

Localities—Upnor, Shorne

Lamellibranchia

- *Corbicula cordata* (Morris)
- *C. cuneiformis* (Férussac)

Lamellibranchia—*contd.*

C. sp. nov. [*sororcula* Edwards MS.]
C. (*Tellinocyclas*) *tellinella* Férussac
C. sp., very tumid forms
C. sp., ridged forms
Cyprina scutellaria Lamarck
Dosiniopsis bellovacensis (Deshayes)
Glycymeris plumsteadiensis (J. Sowerby)
Ostrea bellovacina Lamarck
O. tenera J. Sowerby
Pitaria sp.
Protocardia laytoni (Morris)
Scrobicularia condamini (Morris)
Tellina sp. nov. [*morrisii* Edwards MS.]
Unio subparallela Edwards

Gastropoda

Bythinella websteri (Morris)
Brotia inquinata (Defrance)
Hydrobia sp.
Melanopsis buccinoides Férussac
Planorbis hemistoma J. Sowerby
Stenothyra parkinsoni (Morris)
Tympanotonus funatus (J. Sowerby)

Crustacea

Ostracods

Pisces

Lepidosteus sp.
bones, teeth, scales and vertebrae of bony fishes

BLACKHEATH AND OLDHAVEN BEDS

Localities—Upnor, Hundred of Hoo and High Halstow

Lamellibranchia

Astarte elevata G. B. Sowerby
Corbicula cordata (Morris)
C. cyreniformis (Férussac)
C. sp. nov. [*sororcula* Edwards MS.]
C. (*Tellinocyclas*) *tellinella* Fér.
Corbula arnouldi Nyst
C. sp. nov. [*morrisi* Edw. MS.]
C. regulbiensis Morris
Cyprina morrisii J. de C. Sow.
Cyrtodaria or *Panopaea sp.*
Dosiniopsis bellovacensis (Deshayes)
Glycymeris plumsteadiensis (J. Sow.)
G. sp.
Modiolus mitchelli (Morris)
M. sp.
Nucula sp., probably *N. fragilis* Deshayes
Ostrea bellovacina Lamarck
O. tenera J. Sow.
Panopaea intermedia J. de C. Sow.
Pitaria vagniacarum Wrigley
Protocardia laytoni (Morris)
P. plumsteadiensis (J. Sow.)
Pteria sp.
Tellina, 2 spp.

Gastropoda

Actaeon sp.
Aporrhais aff. *sowerbii* (Mantell)
A. triangulata Gardner
Benoistia lunnii (Morris)
Brotia inquinata (Defrance)
Calyptraea suessoniensis d'Orbigny
C. sp.
Eulima ? subnitida d'Orb.
Euspira glaucinoides (J. Sowerby)
Ficus sp.
Hemipleurotoma spp.
Melanopsis buccinoides Férussac
M. sp.
Natica abducta Deshayes
N. sp.
Odontostomia sp.
'*Parvisipho*' cf. *infraeocenica* Cossmann
Pollia sp.
Polynices sp.
Ringicula lignitarium Cossmann
R. minor Deshayes
Roxania cincta (Deshayes)
R. sp.
Siphonalia mariae (Melleville)
Theodoxus globularis (Férussac)
T. subornatus (d'Orb.)
Tympanotonus funatus (J. Sow.)

Pisces

Ardiodus marriotti White
Chimaera eocaenica Woodward and White
Gadus eppsi Frost (otoliths)
G. eocenicus Frost (otoliths)
Hypolophus sylvestris White
Lepidosteus sp.
Merlangus sp. (otoliths)
Merluccius sp. (otoliths)
Odontaspis (*Odontaspis*) *rutoti* (Winkler)
O. (*Synodontaspis*) *cuspidata* (Agassiz) praemut. *hopei ?* Ag.
O. (*S.*) *cuspidata* praemut. *teretidens* White
O. (*S.*) *macrota* (Ag.) praemut. *striata* (Winkler)
Phyllodus sp.
Squatina prima (Winkler)
Trichiurides orpiensis (Leriche)
T. cf. *sagittidens* (Winkler)
Bones, teeth, scales and vertebrae

Reptilia

Chelonian remains

LONDON CLAY

The London Clay flora of Sheppey has been exhaustively monographed by Reid and Chandler (1933), to which reference should be made. The faunal list is taken from the works of Mr. A. G. Davis, while the inclusion of earlier records is based on his opinion that the old collections were mostly made around Minster. Sheppey is stratigraphically in the position of the fifth or highest of the faunal divisions of the London Clay recognized by A. Wrigley (Wrigley 1940*b*), but the fauna is akin to that of divisions 3 and 4. The sediment of these divisions is a pure, compact clay, like that of Sheppey. The faunal distinctness of division 5 is related to the fact that the clay becomes sandy, heralding the oncoming of Claygate Beds conditions and introducing changes in the fauna. At Sheppey, however, although the Claygate Beds are present above the London Clay, this change in the sediment did not take place as soon, so that the old fauna persisted with less change than elsewhere.

Locality—Isle of Sheppey (western part)

FLORA

Out of some 300 species recorded by Reid and Chandler (1933), of which the great majority occur at Sheppey, the following are abundant:

Monocotyledones

- *Nipa burtini* (Brongniart)

Dicotyledones

- *Anonaspermum commune* Reid and Chandler
- *Cantitilia polysperma* R. and C.
- *Cinnamomum globulare* R. and C.
- *Cupanoides grandis* Bowerbank
- *Dracontomelon minimum* R. and C.
- *Dunstania multilocularis* R. and C.
- *Faboidea crassicutis* Bow.
- *Hightea elliptica* Bow.
- *Icacinicarya platycarpa* R. and C.
- *Iodes corniculata* R. and C.
- *I. multireticulata* R. and C.
- *Lagenoidea bilocularis* R. and C.
- *L. trilocularis* R. and C.
- *Langtonia bisulcata* R. and C.
- *Laurocarpum paradoxum* R. and C.
- *Leyrida bilocularis* R. and C.
- *Mastixia parva* R. and C.
- *Meliosma cantiensis* R. and C.
- *Ochrosoidea sheppeyensis* R. and C.
- *Oncoba variabilis* Bow.
- *Palaeallophyllus ovoideus* R. and C.
- *Stizocarya communis* R. and C.
- *Tinospora excavata* R. and C.
- *Tricarpellites communis* Bow.
- *Wetherellia variabilis* Bow.

FAUNA

Hydrozoa

- *Graphularia wetherellii* Edwards and Haime

Anthozoa

- *Paracyathus brevis* Edwards and Haime
- *P. caryophyllus* Lamarck

Asteroidea

- *Astropecten crispatus* Forbes
- *A. stokesii* Forbes
- *Ophioglypha wetherelli* (Forbes)

Echinoidea

- *Schizaster sp.*

Vermes
- *Ditrupa plana* J. Sowerby
- *Rotularia bognoriensis* (Mantell)
- supposed hooklets of parasitic worms

Polyzoa
- various undescribed forms

Brachiopoda
- *Lingula tenuis* J. Sowerby
- *Terebratulina striatula* J. de C. Sowerby

Lamellibranchia
- *Anomia scabrosa* Wood, frequently found on *Terebratulina*
- *Astarte filigera* Wood
- *A. rugata* J. Sow.
- *Axinus angulatus* J. Sow.
- *Cryptodon goodhalli* (J. de C. Sow.)
- *Cuspidaria inflata* (J. de C. Sow.)
- *Cyprina planata* (J. de C. Sow.)
- *Glycymeris decussata* (J. Sow.)
- *Modiolus depressus* (J. Sow.)
- *Nucula sp.*
- *Nuculana amygdaloides* (J. de C. Sow.)
- *Ostrea gryphovicina* Wood
- *Pinna affinis* J. Sow.
- *Pitaria tenuistriata* (J. de C. Sow.)
- *Protocardia nitens* (J. Sow.)
- *Pteria media* (J. Sow.)
- *Pt. papyracea* (J. de C. Sow.)
- *Teredo sp.* (*T. antenautae* J. Sow. was described from the shell alone, from which it is impossible to place the species accurately in the modern classification)
- *Verticordia sulcata* (J. Sow.)

Gastropoda
- *Acrilla cymaea* Wrigley
- *Aporrhais sowerbii* (Mantell)
- *Bathytoma granata* (Edwards)
- '*Cassis*' *striata* J. Sow.
- *Crenilabium elongatum* (J. de C. Sow.)
- *?Cyrtochetus sp.*
- *Euspira glaucinoides* (J. Sow.)
- *Euthriofusus complanatus* (J. de C. Sow.)
- *Ficus multiformis* Wrigley, typical form
- '*Fusinus*' *wetherelli* Wrigley
- *Hemipleurotoma conica* (Edw.)
- *H. fasciolata* (Edw.)
- *H. konincki* (Edw. *non* Nyst)
- *H. selysi* (Edw. *non* de Koninck)
- '*Litiopa*' *sp. nov.* [*sulculosa* Edw. MS.]
- *Mathilda sororcula* Wrigley
- *Newtoniella charlesworthi* (Prestwich)
- *Orthochetus elongatus* Wrigley
- '*Patella*' *sp.* (minute)
- *Pseudoneptunea curta* (J. Sow.)
- *Pseudotoma topleyi* von Koenen
- *Ptychatractus* aff. *interruptus* (Pilkington)
- *Sassia morrisi* Wrigley
- *Solarium* (*Solariaxis*) *pulchrum* J. de C. Sow.
- *Surculites bifasciatus* (J. Sow.)
- *S. sp. nov.* [*velatus* Edw. sp. MS.]

Gastropoda—*contd.*

Tibia lucida (J. Sow.)
Tornatellaea aff. *simulata* (Solander)
Turricula conica (Edw.)
T. crassa (Edw.)
Volutospina nodosa (J. de C. Sow.)
Xenophora extensa (J. Sow.)

Scaphopoda

Dentalium anceps J. de C. Sow.

Pteropoda

Minute, thin, planorbiform shells of the genera *Spiralis* and *Valvatina*
Camptoceratops priscus (H. H. Godwin-Austen)

Cephalopoda

Beloptera (*Belopterina*) *levesquei* d'Orbigny
Belosepia blainvillei (Deshayes)
B. sepioidea (Blainville)
Aturia ziczac (J. Sowerby)
Hercoglossa cassiniana Foord and Crick
Nautilus sowerbyi J. de C. Sowerby
N. urbanus J. de C. Sow.
N. (*Cimomia*) *centralis* J. Sow.
N. (*Eutrephoceras*) *imperialis* J. Sow.

Crustacea
(Cirripedia)

Scalpellum minutum (Brown) in vast numbers associated with *Teredo*-bored timber
S. quadratum (Dixon)

(Malacostraca)

Homarus gammaroides (McCoy)
Plagiolophus wetherelli Bell
Xanthopsis nodosa (McCoy)

Pisces

Ardiodus marriotti White
Cybium sp.
Cylindracanthus rectus (Agassiz)
Isurus nova (Winkler)
Lamna obliqua (Ag.)
Monocentris sp. (otoliths)
Myliobatis toliapicus Ag.
Odontaspis (*Synodontaspis*) *cuspidata* (Ag.) praemut. *hopei ?* Ag.
O. (*S.*) *macrota* (Ag.)
Ophidium spp. (otoliths)
Pericidarium plebejius Koken (otoliths)
Physodon tertius (Winkler)
Rhinoptera daviesi Woodward
Scyliorhinus minutissimus (Winkler)
Serranus noetlingi Koken (otoliths)
Squatina prima (Winkler)
Trichiurides sagittidens (Winkler)

Reptilia

Crocodilus spenceri Buckland
Palaeophis toliapicus Owen
?P. typhaeus Owen
Argillochelys antiqua (Koenig)
A. cuneiceps (Owen)

Reptilia—*contd.*

- *A. convexa* (Owen)
- *A. subcristata* (Owen)
- *Chrysemys bicarinata* (Bell)
- *Ch. testudiniformis* (Owen)
- *Dacochelys delabechei* (Bell)
- *Eosphargis gigas* (Owen)
- *Homopus comptoni* (Bell)
- *Lytoloma crassicostatum* (Owen)
- *L. planimentum* (Owen)
- *Podocnemis bowerbanki* (Owen)
- *Thalassochelys sp.*
- *Trionyx pustulatus* Owen
- *Trionyx sp.*

Aves

- *Argillornis longipennis* Owen
- *Dasornis londiniensis* Owen
- *Halcyornis toliapicus* (Koenig)
- *Lithornis vulturinus* Owen
- *Odontopteryx toliapica* Owen
- undetermined Carinatae (including Gallininae)

Mammalia

- *Argillotherium toliapicum* W. Davies
- *Coryphodon eocaenus* Owen
- *Hyracotherium leporinum* Owen

R.V.M.

References

CRICK, G. C. 1901. Note on a dibranchiate cephalopod from the London Clay of Sheppey. *Proc. Malac. Soc.*, vol. iv, p. 256.

DAVIS, A. G. 1936. The London Clay of Sheppey and the location of its fossils. *Proc. Geol. Assoc.*, vol. xlvii, p. 328.

—— 1937. Additional notes on the geology of Sheppey. *Proc. Geol. Assoc.*, vol. xlviii, p. 77.

NEWTON, R. B. 1891. *Systematic list of the F. E. Edwards Collection of British Oligocene and Eocene Mollusca.* Brit. Mus. (Nat. Hist.).

—— and G. F. HARRIS. 1894. A Revision of the British Eocene Cephalopoda. *Proc. Malac. Soc.*, vol. iv, p. 256.

PRIEST, S. and F. J. EPPS. 1935. Field meeting at Higham and Shorne, Kent. *Proc. Geol. Assoc.*, vol. xlvi, p. 61.

REID, E. M. and M. E. J. CHANDLER. 1933. *The London Clay Flora.* Brit. Mus. (Nat. Hist.).

WHITAKER, W. 1872. The Geology of the London Basin. *Mem. Geol. Surv.*, vol. iv.

—— 1889. The Geology of London and part of the Thames Valley, vol. i, *Mem. Geol. Surv.*

WHITE, E. I. 1931. *The Vertebrate Faunas of the English Eocene, vol. i.* Brit. Mus. (Nat. Hist.).

WRIGLEY, A. 1938. English Eocene Strombidae and Aporrhaidae. *Proc. Malac. Soc.*, vol. xiii, p. 61, pls. iv-vi.

—— 1940*a*. Some Eocene Mollusca, with descriptions of new species. *Proc. Malac. Soc.*, vol. xxiv, p. 6.

—— 1940*b*. The Faunal Succession in the London Clay, illustrated in some new Exposures near London. *Proc. Geol. Assoc.*, vol. li, p. 230.

—— 1944. English Eocene Eulimidae, with notes on the Torsion of *Eulima* and on Charlesworth's illustrations. *Proc. Malac. Soc.*, vol. xxvi, p. 49.

Chapter IX

PLEISTOCENE AND RECENT

THE PLEISTOCENE DEPOSITS of the Chatham area may be divided into two main groups, Head Deposits and River Deposits. The latter comprise the terraced gravels and alluvium of the rivers, and the former the Clay-with-flints of the Chalk plateau, gravels, brickearth, and other deposits all of which are normally of a structureless and often rubbly character, not to be classed either with true glacial deposits or with river deposits. They may result from solifluction, hillcreep or wind action. Certain of them contain mollusca associated with a temperate climate.

Head drifts have not usually travelled far from their sources of origin; they may occur capping high ground, on hill slopes, or in valley bottoms, and in some instances have been derived mainly from pre-existing deposits of similar origin.

River deposits, occurring more or less in well-defined terraces, may be assigned with some degree of confidence to relative positions in the time-scale; but Head deposits are less easily placed in a chronological sequence.

The oldest Head deposit is the Clay-with-flints, probably in this district accumulated mainly by solifluction. Its formation was succeeded by that of the 4th, 3rd and 2nd River Terraces (p. 136) of the Thames and Medway, at respective levels of approximately 200 ft, 100 ft and 50 ft O.D.; the last-named has yielded Acheulian implements (p. 140). The next episode appears to have been the formation by solifluction of a head, sludging down the dip-slopes of the Chalk and of the Eocene strata, and incorporating much material from the Clay-with-flints and the Eocene. These are conveniently described below under the heading of 'Older Head Deposits'.

During a succeeding erosion stage it is thought that the Chalk coombes of the district were largely formed, and were eroded to perhaps a little below Ordnance Datum level along the lower parts of their courses. This erosive action which dissected the sheets of Older Head, was followed by the deposition of the 1st Terrace of the River Gravels, extending upwards from Alluvium level to about 30 ft O.D. Towards the end of the 1st Terrace period, a 'Younger Head', again mainly gravel but associated with extensive deposits of Brickearth, was formed. This gravelly head is the equivalent in part of the Dry Valley Gravels of adjacent areas. Of still more recent origin are extensive mixed deposits of hillwash, mantling hill slopes and accumulating in valley bottoms, described below under the heading of Hillwash Head.

Among the Head group of deposits is a Chalk Breccia, of restricted occurrence, and of obscure origin.

Except for the Clay-with-flints these various subdivisions of Head deposits are not separately shown on the Geological Map; indeed, while their history may be determined in a general way, it is not possible to insert satisfactory boundary lines between them. On the other hand, they are divisible with some degree of reliability into three lithological types—gravel, brickearth, and mixed deposits, and this method of subdivision has accordingly been adopted on the Geological Map.

The great variability in type of these deposits, and their widespread occurrence, were noted in particular by T. McKenny Hughes, whose manuscript notes foreshadow the present classification. He distinguished an 'Older Gravel' of subangular flints, with Tertiary pebbles, from a lower level type associated with brickearths; but found it impossible to separate many low-lying gravels and brickearths into respective groups of fluviatile or sub-aerial origin since the latter pass into and are re-sorted by streams and rivers at the lower levels. Exceptionally he separated a browner and more clayey rainwash brickearth from a fluviatile brickearth, and also noted the influence of local sources of material on the nature of the drift and cites a section seen in the chalk-pit west of the mouth of Strood tunnel (*see* Whitaker 1872, p. 28) to illustrate the formation of chalk rubble by decomposition of the chalk in place.

J.A.R., S.C.A.H., F.H.E.

CLAY-WITH-FLINTS

Much of the Chalk plateau south of Watling Street is covered by Clay-with-flints, the lower, northern, limit lying just below the 200-ft contour except near Chatham and Stockbury where it lies about 250 ft O.D. The deposit, which had at one time extensively covered the Chalk, is now much dissected by numerous dry valleys which cut through the Clay-with-flints into the underlying Chalk.

Several theories for the origin of the Clay-with-flints have been advanced (*see* Sherlock and Noble 1912, p. 199; Dines and Edmunds 1933, p. 149; Dines and others 1940, p. 198), including residual accumulation by solution of Chalk, glacial action and periglacial action producing a mixed series of previously distinct local beds.

In the present area a widespread type of Clay-with-flints consists of sandy loam with varying amounts of battered flints and a few pebbles derived from the Eocene Beds, but stiff dark-red clay with unworn flints is also developed, particularly on some of the higher levels of the Chalk dip-slope, e.g. north-west of Lidsing. On the highest parts, near the escarpment crest, the deposit is frequently more variable as near Bredgar and south-east of Tickham, near Norton. The average thickness of the Clay-with-flints is about 4 ft, but irregular solution-hollows and solution-pipes in the Chalk, both commonly containing sand from the Thanet Beds and other Tertiary materials, account for the greater thicknesses frequently met with in borings or excavations. Such disturbed masses are also liable to occur anywhere in the areas shown as bare chalk, but especially on high ground and near the Clay-with-flints boundary. Their lateral extent is usually not more than a few yards.

Patches of gravelly loam associated with the Clay-with-flints have yielded flint flakes claimed as Eolithic implements. Mr. J. P. Johnson (1902, p. 207) has described, from near Walderslade, both unworn and rolled implements and suggests that they may be derived from possible relics of early drift deposit.

Ironstone of Lower Greensand, Eocene and Pliocene origins, and soft sandstone and hard quartzitic 'sarsens', probably from the Eocene, are found in the Clay-with-flints. The deposit often approximates to a brickearth, with few flints, where it rests on outliers of Thanet Sand.

Near Great Wood and Ranscombe, south-west of Strood, the Clay-with-flints is a heavy red-brown loam with unworn flints, ochreous subangular flints, Tertiary pebbles and lumps of chert; it appears to merge with hillwash connected with the patch of supposed Pliocene gravel (*see* p. 94) on the highest ground in Great Wood. Elsewhere it is more clayey, though pebbly and loamy in parts, and was well seen in three large pipes, some 50 ft deep, in the chalk-pit half a mile north by east of Upper Halling. Ironstone of southerly derivation from the Lower Greensand lying on the plateau about half a mile north-west of Upper Halling may be related to a drift of very early date.

East of the Medway, around Burham Hill, where many large white flints were noted, the clay is variably loamy, and between the Robin Hood and Little John Inn and Bluebell Hill, ironstone and lumps of sarsen stone are of common occurrence. About 650 yd north-west of Burham Hill an old pit showed in a solution pipe sandy loam derived from the Thanet Beds, with Clay-with-flints apparently both intermixed and overlying it. A number of drift-filled pipes occur on the Chalk spur about half a mile E.N.E. of Ringshill Place and in the valley head north of the Robin Hood and Little John Inn.

Much of the ground in Weeds Wood is flinty red clay but at Aylesford Common, around Cossington Fields and in Westfield Wood, and farther south-east, there is much loam, together with ironstone and sarsens. Old pits 500 yd south-west of Cossington Fields showed the drift with a minimum thickness of 6 ft resting irregularly on the Chalk, and enclosing a number of fine, granular, partly silicified sarsens. Two well-developed pipes seen in the chalk-pit 350 yd north by west of the Lower Bell contain both Tertiary pebbles and sarsens.

Sarsens and ironstone, with subangular white flints, occur on the plateau south of Capstone, south-east of Chatham; the ironstone is partly soft and sandy and partly of a coarse type characteristic of the Lower Greensand. Large and small Tertiary pebbles are also locally abundant. In Lords Wood there is both red clay and brown loam, the latter sometimes having the appearance of a weathered product of the former. Locally there are pebbly and sandy patches, with lumps of ironstone, sandstone and large sarsens. South-west of Dunn Street and north-west of Bredhurst, hard iron-stained sarsen is common, both as small lumps and as large doggers.

About Bredhurst some of the loose ironstone is thin, and rather suggests a Pliocene origin. A pit 450 yd north-west of Abbots Court Farm showed a large pipe of mixed Clay-with-flints and Thanet Beds over which appeared to extend a loamy clay, with fractured nodular flints. A chalk-pit 100 yd to the N.N.W. exposed a pipe containing contorted masses of dark glauconitic loamy clay and fine sandy loam with ironstained quartzite and many large flints. South of Rainham Park the Clay-with-flints includes a good deal of glauconitic loam from the Thanet Beds. Locally worn brown flints associated with Lower Greensand ironstone, and green-coated flints from the basal Thanet Beds, are common.

North-westwards through Wigmore and East Hoath Wood to Darland Hill and the outskirts of Chatham most of the drift is red-brown flinty clay, partly loamy due to material from the Thanet Beds.

South-east of Bredhurst the thickness varies from 2 ft at Cowstead to 10 ft south-west of South Street. Patches and pipes of sandy Thanet Beds material are of frequent occurrence. Ironstone from the Lower Greensand was noted north and west of South Street, east of Cockhill and also in the smaller spreads south-east and south-west of Lower Cox Street, south-west of Scragged Oak and in Bredhurst Hurst. Around Scragged Oak Tertiary pebbles are particularly abundant on the west side. S.C.A.H.

West of the main road running south from Sittingbourne through Tunstall, the Clay-with-flints is a typical sandy loam with battered flints.

At the southern end of Frid Wood and at Deans Hill are two small deposits about 3 ft thick of dark red clayey loam with unworn flints. East of Deans Hill the Clay-with-flints approaches a flint gravel about 3 ft thick. South of Pett Farm the deposit is fairly stiff loam with flints, while towards Oad Street, nearer the outlier of Thanet Beds, it consists of a sandy loam with few flints and Eocene pebbles. J.A.R.

HEAD DEPOSITS: OLDER GROUP

Head deposits of an older group, mainly gravels, occur on high ground, are not associated with brickearth and differ from the terraced river gravels in the general absence of pieces of chert derived from the Lower Greensand. They are remnants of one or perhaps of several sheets of Head which formerly covered the gently-sloping platform in the eastern half of the area, and are largely associated with major dry valleys. It is possible that gravels of several ages are included in this group. They include the pebbly gravels sloping north from 240 to 180 ft O.D. on the Isle of Sheppey.

In general ochreous subangular to angular flints are the main constituent. A temporary section in the deposit south-east of Woodstock showed the flints as being stained in situ by contact with ferruginous sand. The relative percentages of battered, uncoloured flints and of pebbles from the Eocene Beds vary with the situation of the gravel.

The deposits which may be up to 10 ft thick but are more usually about 3 ft, were at one time dug for road-metal but are now little used.

DETAILS

About half a mile south of Upchurch, at 100 ft O.D., a thin spread includes flints, mainly ochreous and angular to subangular, some pebbles, and grey and black flint still retaining pieces of cortex. North of Dane House, about a quarter of a mile north of Hartlip Church a thin patch of subangular ochreous flint gravel at 160 ft O.D., which appears to merge with the Brickearth on the side of the valley, is doubtfully regarded as being of the older group.

On the flat-topped ridge west of the valley through Stockbury three thin spreads north of the railway lying at 160 ft to 120 ft O.D. are regarded as remnants of older gravel as also are a small patch at Nether Toes near Bramblefield at about 80 ft O.D., and gravels south of the railway at levels varying from 240 ft to 195 ft O.D.

Two patches west of Chestnut Street, are composed of about 90 per cent of derived Woolwich pebbles with some subangular ochreous flints and pieces of sandstone of clear quartz grains cemented by limonite, and associated with the gravel is a coarse sand weathering a rusty colour very similar to Woolwich sand. These deposits are mainly disturbed basal bed of the Woolwich Series, and several shallow pits show about 3 ft of gravel over Thanet Beds.

A section near Keycol and on the south side of Watling Street, showed up to 4 ft of flint gravel resting on Woolwich Beds. The flints are battered but many still retain pieces of cortex; most are pale grey in colour though a few are ochreous.

On the east side of the Stockbury valley, gravel extends from about 250 ft to 230 ft O.D., and consists for the most part of grey and whitish flints, much battered, such as would be derived from the Clay-with-flints.

On both sides of the dry valley immediately east of Sittingbourne, the high ground around Woodstock at 230 ft to 180 ft O.D., has a covering of flint gravel, a temporary section south-east of Woodstock showing up to 6 ft of angular and subangular flints mixed with a somewhat coarse ferruginous sand. On the ridge east of the valley, gravel rests at levels of from about 230 ft down to about 150 ft O.D.

South of Rodmersham Green, at the north end of Cheney Wood (of the 6-in map Kent 33 S.W.), gravel comprises flints, more than half of which are ochreous and of which about 60 per cent are angular, and about 10 per cent are pebbles, some being about 2 inches in diameter.

About 1 mile south-east of Sittingbourne Railway Station a section, much obscured by rubbish, showed about 5 ft of dirty gravel consisting mainly of stained flints, a few still retaining parts of their cortex, and some pebbles.

Around Scuttington Manor about a mile west of Lynsted, is a little gravel and mottled sandy clay, the latter apparently disturbed Thanet Beds.

East of Barrow Green, near Teynham, two small spreads of flinty gravel with pebbles lie one on either side of, and 200 yd to 300 yd from the railway. Much of the material from the northern patch has been dug for road metal. The deposit comprises subangular ochreous flints with Eocene pebbles and an occasional piece of sandstone such as forms doggers in the Woolwich Beds. Whitaker records the finding of an implement of Palaeolithic type.

J.A.R.

West of the Medway, between Shorne and Higham Upshire, on Broom Hill and along the south side of Watling Street, between there and Park Pale, are several patches of an older head gravel between 150 ft and 200 ft. These may represent a 4th Terrace river gravel but are now only remnants of gravelly material containing ochreous and white flints, Tertiary pebbles and Lower Greensand chert. Salter (1905, p. 6) noted much Wealden sandstone at 200 ft O.D. on Strood Hill. The gravels seem to have contributed to a considerable extent to the surrounding spreads of hillwash covering the local outcrops of Thanet Beds and Chalk. H.G.D.

HEAD DEPOSITS: YOUNGER GROUP

Head Deposits of a younger group, associated with brickearth, occur mainly in the eastern half of the area, lying on the sides and in the bottoms of the valleys. Many consist of gravel, of the type classed in adjacent areas as 'Dry Valley Gravel' and were deposited after the formation of the present topography. In the lower, northern, parts of the several valleys, separated by wide and flat dividing ridges, most of these deposits appear to have been derived from the head-gravels of the older group, notably at Upchurch and Bobbing; to the south, they are derived largely from the Clay-with-flints, which has slumped down the comparatively steep valley sides. An angular gravel is thus formed in the upper parts of most of the dry valleys in the eastern half of the area. Gravels of this group merge with the Brickearth, beneath which they usually continue, but they may be tongued up into it or may occur as rafts; or may be absent beneath it.

These gravels, of which the usual constituents are subangular ochreous flints, have been dug in places as road metal but constitute a nuisance in brickearth diggings. Where they occur at the surface they are usually about 3 ft thick but beneath the brickearth they have been found with a thickness up to 5 ft or 6 ft. Some areas, especially in the bottoms of the valleys, had at one time a covering of brickearth which has since been dug off.

These younger head deposits may merge into hillwash.

DETAILS

North and east of Upchurch deposits of gravel and brickearth which grade into each other extend from the high ground on which the village is built, down to the Thames alluvium. According to local information, a considerable amount of the best brickearth has long been removed, no signs of the old pits remaining. Upchurch is built on a patch of gravel possibly derived from an older spread about a quarter of a mile to the south, and about a quarter of a mile east of the village gravel comes to the surface, the flints composing it being small, sharp, and grey in colour. On the west side of the lane running north-east from Ham Green, about three-quarters of a mile north of Upchurch, a shallow pit exposed a coarse red sand with ochreous flint gravel, and a temporary pit 300 yd south of Bayford showed 1 ft of made ground over 6 ft of somewhat dirty angular flint gravel resting on sand of the Woolwich Beds. On the edge of the alluvium, north from Upchurch, a small pit showed clayey sand and subangular flint gravel under about 1 ft of alluvial mud.

South of Upchurch the railway-cutting south of Gore House exposed sand and gravel of a spread covering the west side of the dry valley through Hartlip and merging with brickearth towards the bottom. Coarse mottled sand up to 4 ft thick covers sand and ochreous flint gravel 2 ft to 3 ft thick which itself rests on Woolwich Beds.

Near Hartlip, and south of the Watling Street, removal of brickearth has exposed a flint gravel; on the west side of the road to Hartlip and 700 yd south of Watling Street a 5-ft face showed a sandy mixture of angular to subangular flints white to ochreous in colour, and some chalk pebbles. This deposit, as it is traced southwards up the valley, merges into, and can be seen to be derived from, head from the Clay-with-flints.

Flint gravel comes to the surface through the overlying brickearth 200 yd south of Elm Farm, Lower Halstow.

In the south side of the railway-cutting, just east of the road bridge, at Cold Harbour, Bobbing, about 4 ft of coarse reddish-brown sand and subangular ochreous flint gravel are exposed.

In the neighbourhood of Rose Hill west of Sittingbourne, gravel appears from beneath brickearth to the north and north-west and covers the area to a depth of about 3 ft. Shallow pits, now overgrown, indicate that a considerable amount of this has been dug near the western limit of the spread. Gravel in the valley was formerly extensively dug near Chestnut Street, Stockbury. On the west side, pits, 6 ft to 8 ft deep, showed dirty gravel composed of flints, of various sizes, stages of angularity and colouring, and some pebbles. South of Rose Hill the gravel in the valley is covered by a few feet of brickearth but it again comes to surface near Milton Regis where much digging of brickearth and dumping of waste material has occurred. An exposure 730 yd east of Milton Church, showed 3 ft of dirty gravel composed mainly of ochreous flints.

The valley east of Sittingbourne, running from Highsted Forstal to east of Murston, is floored with gravel. A degraded pit in the deepest part of the valley south-east of Woodstock, about 5 ft deep, exposed a clayey sand covering and mixed with gravel.

North of the Watling Street the ground has been much disturbed by gravel digging but some gravel still remains. About 500 yd west of Tonge Church a face of a brickearth pit showed at one point about 6 ft of fine brown clayey silt with pockets of gravel and at another point farther west gravel extended upwards in tongues into the brickearth.

A thin spread of gravel at Little Murston lies at levels varying from about 25 ft down to 12 ft O.D., and comprises angular flints, some ochreous, and pebbles up to 1 inch in diameter. Several overgrown pits indicate the deposit to be only a few feet thick.

A much degraded brick-pit 200 yd south-west of Haywood, south-east of Bapchild, exposed gravel intermittently between the brickearth and the Chalk. In 1927 flint implements of Early Levallois culture were found (Dines 1927) when a thin horizontal bed of flints was to be seen in the brickearth.

The shallow valley about half a mile east of Tonge Church is floored with a thin spread of flint gravel, which in places south of the railway, has been dug along with the associated brickearth. J.A.R.

On the Chalk outcrop at Cliffe, an area just south of the village forms a fairly flat plateau-like feature up to 50 ft O.D., which is covered with a chalky head—the Coombe Deposit of the area to the west (Sheet 271). Though not a head gravel in the strict sense, this deposit may belong to the period of formation of these younger head gravels and is described here for convenience. On the north and west of the plateau the Chalk forms a subdued cliff along the edge of the alluvium, and on the east and south the ground slopes gently to below 25 ft O.D. The top of the plateau is covered by 4 ft to 5 ft of the chalky deposit which was well exposed in 1937 in the eastern end of the chalk quarry about three-quarters of a mile south-west of Cliffe Church. The soil, about 18 in thick, is a grey loam with coarse sand grains, angular flints and a few Tertiary pebbles and rests on 2 ft to 4 ft of white to pale biscuit-coloured loam with a coarse sand content. It consists mainly of chalk fragments from about 1 inch diameter down to pea-size and contains scattered angular flints, a few Tertiary pebbles and streaks of sand. Faint signs of flow structure are observable here and there and the deposit rests on a very irregular surface of flaggy chalk, into which it is pocketed and festooned. At the top, and immediately below the soil, there are lenses and pockets of reddish brown, coarse sandy loam with scattered stones, apparently the result of decalcification of the deposit.

In the chalk pit half a mile north-west of the above, the deposit, about 3 ft or 4 ft thick generally, is in places let down into solution pipes in the Chalk, up to 20 ft deep and 12 ft across at the top. Capping the plateau, the spread is cut off on all sides from higher ground. A small patch of similar material occurs a quarter of a mile west-south-west of Cooling Church, and there is another occurrence on the opposite side of the Thames at East Tilbury, where, in 1921, an exposure close to the edge of the alluvium showed similar chalky rubble with large chalk flints and smaller stones, some set with longer axes vertical, decalcified in irregular patches to brown loamy gravel. The deposit here is 8 ft thick and rests on an irregular, pitted surface of Chalk.

Another deposit which appears to be referable to the younger group of head deposits is an occurrence of irregular layers of gravel, sand and clay with race that skirts the lower part of the river-cliff feature on the left bank of the Medway at Upnor. The deposit (not shown on the 1-in geological map) forms a narrow and intermittent strip and is banked against the cliff which is composed of Chalk and Thanet Beds with a capping of gravel and brickearth. Its constituent layers, though nearly horizontal on the riverward side, rise steeply westwards against the cliff. A gravelly deposit in this position, south of Upnor Castle, is referred to by G. E. Hutchings (1925, p. 427) as his 'Twenty-five Foot Terrace' of river gravel, but its position and the structure of a similar deposit as seen farther south, show that it may be a coombe deposit produced by slumping off the cliff face. At some date before 1913, *Elephas antiquus* had been found in the basal parts of this deposit, about due east of the summit of Tower Hill (Andrews 1915, p. 398; Andrews and Cooper 1928). The section at the site of the excavation showed, according to G. Barrow (in MS.):

	Ft	in
Surface wash and brickearth mixed with a few scattered stones ..	4	0
Thin film of clay cemented by iron-oxide		1
The beds below this are all more or less bedded and slope towards the river.		
Finely laminated loamy sand with a layer of small pebbles and flints at the base		6
Pale, sandy, iron-stained, loamy clay		5
Fine, nearly white loamy sand		10
Line of scattered stones, slightly larger than above		1
Sand passing down into sticky clay		10
Gravel with lenticles of clay		11
Grey clay, gravelly below, in which elephant remains were found ..		?
Thanet Beds		–

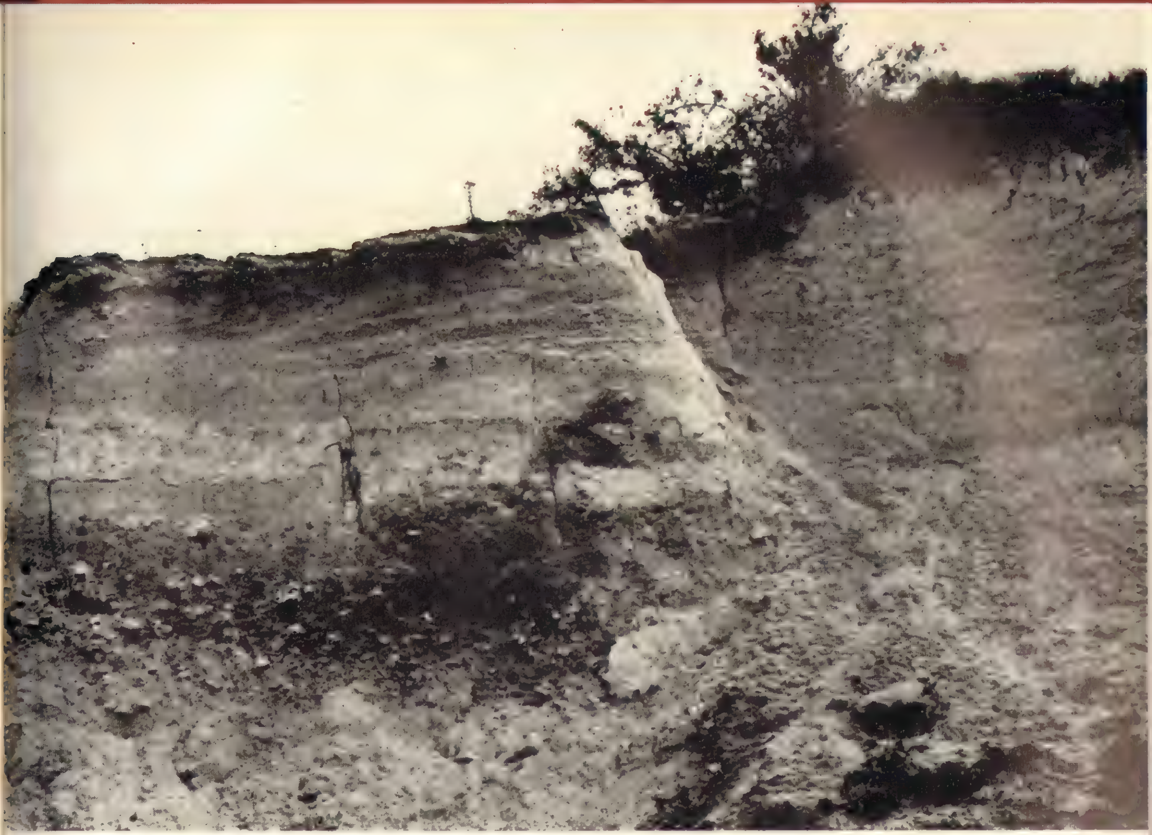
This section agrees fairly well with a description by Andrews which gives 5 ft for the thickness of the basal bed which is said to contain much race.

H.G.D.

BRICKEARTH

The name 'Brickearth' is given to superficial deposits of buff, brown or red, more or less homogeneous, structureless loam or silt, mostly non-calcareous, and requiring little or no admixture of other material to render them suitable for brickmaking. In this district deposits of this type mantle the gentle topographical features of the south side of the Thames estuary. The earliest known use of the term, according to the Oxford Dictionary, was in 1667; it has subsequently been adopted from the brickmaking industry by the geologist, at first as descriptive of this distinct lithological rock-type, but later as a somewhat vague stratigraphical term, from an apparent relationship of the deposits with the terraced river gravels with which they are frequently associated.

In structure, lithology and mode of occurrence, brickearths bear a strong resemblance to the wind-borne loess deposits of the continent. On the other



(A 7894)

A. Head deposit on Chalk, Upper Halling

PLATE IV

B. Brickearth dug for brickmaking, Perryfield, Bobbing

(A 7964)

hand, the close association of the brickearths of the valleys with terraced river gravels has given rise to a view that, in point of age and origin, they may be classed with the terraced gravels on which they may rest, while yet another view is that the mode of formation of brickearths is by solifluction. Godwin-Austen (1857, p. 63) regarded the brickearths occurring near the coast of Sussex, as the wash of a terrestrial surface, under a far greater amount of annual rainfall than we have at present.

Prestwich (1865, p. 272) regarded the brickearth of South-East England and of Northern France as loess in almost every respect identical with the loess of the valley of the Rhine. He considered it to be of river origin and accounted for the small, scattered, angular stones it contains as due to floating shore ice, but he also noted that in places the loess put on a local character, derived from either adjacent chalk, sand, or clay beds, when it became so modified as to render its true character not easily distinguishable. In some cases, he noted it became very argillaceous, in others very sandy or very chalky. Occasionally it is so full of angular rock—or flint-fragments—as to pass into an angular gravel. He, therefore, like Godwin-Austen, favoured a downwash or sludge process not necessarily associated with a cold climate.

H. J. Osborne White, discussing the brickearth of the Dover area, with which much of that of the present district is comparable, regards the accumulations largely as being the outcome of widespread 'alluviation', or 'sheet-flooding'; and concludes that wind also played a part (1928, p. 63).

The district along the south side of the Thames estuary, eastwards of Strood, has long been known to be a main area of brickearth occurrences in England. By far the majority of these show a lithological resemblance to the softer parts of solid formations upon which, or close to which, they rest. Thus deposits on or near Thanet Beds outcrops are generally of a finely sandy nature, those adjacent to Woolwich Beds are more coarsely sandy, while those close to or on London Clay are distinctly clayey. Moreover, many occurrences contain scattered stones which could hardly be accounted for by wind transportation and in areas near the Chalk outcrop the brickearths are calcareous and in places contain small scattered pellets of chalk. It is noteworthy, also, that within the present district brickearth is almost entirely confined to the areas of Tertiary outcrops.

Some localized brickearths may well be attributable to wind action, but arid conditions did not generally prevail, for a 'damp' molluscan fauna is recorded from Sittingbourne and Teynham (*see* pp. 133, 134).

In many instances the deposits pass downwards into a gravelly layer, 1 ft to 3 ft thick, which in places may be tongued up into the brickearth or may occur as bunches or rafts of stones even several feet above the base; again, where gravelly head occurs on higher surface levels it may be traced down the slope, passing by gradual stages into brickearth; both the above phenomena are suggestive of movement by solifluction. Much of the Kent brickearth appears to have been formed by solifluction, possibly at various temperate interludes during the Glacial period, when the movement of the mud-streams was slight and insufficient to transport heavier material such as coarse gravels.

Prestwich (1892, p. 307) pointed out the significance of the fauna of 'only land-shells and the remains of land-animals' in the 'Rubble-drift or Head' generally, with which he includes brickearths (and associated gravels) around

Upchurch, Sittingbourne, Frindsbury and in the Luton valley, and described how locally the drift drapes the slopes of the hills before it spreads out in the lower ground. Newton (1904, p. 62) records bones of *Elephas primigenius* and *Rhinoceros antiquitatis* found in abundance 1 furlong south-east of Tonge Church. The close link between brickearths and the undifferentiated hillwash described below (p. 124) is emphasized by a similarity of fauna. While elements in the mammalian fauna suggest both cold and mild climates the mollusca are those of mild damp conditions.

Much of the brickearth of the present district, therefore, is shown on the geological map as 'Head-Brickearth'. Certain spreads however, especially near rivers, are classed as 'River-Brickearth'. These seldom exceed a height of about 50 ft above the present river level, and in some rare cases show signs of bedding. Their material is generally paler in colour than the head-brickearth; they are frequently gravelly at the base and in most cases, especially at their landward margins, are covered by a red head-brickearth, distinguishable from the river deposit by its darker colour, its rougher or harsher texture, and frequently by the development of a coarsely columnar structure, while an irregular, wavy streak of gravelly material, up to a foot or so thick, generally separates the two. The river-brickearth shows signs of having been formed from head-brickearth, in water in which currents were absent or very gentle. Its occurrence intercalated with beds of sand around Halling in terrace-like spreads resting on, or banked up against, eroded slopes of Chalk and extending from about 50 ft O.D. down to the saltings level is recorded by Cook (1914, p. 220). The deposit also rests on Low Terrace gravels at Borstal, Halling, Strood and Cuxton; from the mammalian and molluscan fauna of the former, Cook concluded that the beds comprised in the low terrace of the Medway are pre-Holocene in age. The character and relationship of both types of brickearth are well seen in the extensive excavations around Hoo.

Like the other head deposits the distribution of brickearth is generally more widespread on the west side of valleys (*see* p. 129) than on the east. The minute holes that give brickearth its porosity, and which may be due to root hairs, are more or less evenly distributed throughout the thickness of the deposits.

Some brickearths of the present area, however, very closely resemble the loess of Europe. Brickearth worked three-quarters of a mile west of Newington, for example, has every appearance of a true loess. Here, in 1950, about 6 ft of buff loam were seen in section to overlie, and to be clearly distinguishable from, the Thanet Sand.

On this point Dr. K. C. Dunham reports: 'The resemblance between many of the brickearths and the loess of North Germany was confirmed by comparison of size-analysis of five samples from the present area with an analysis of a typical loess sample. Down to 300-mesh B.S.S. the sizing was determined by wet-sieve methods, using as consistent a technique as is possible with non-mechanical apparatus. The sub-sieve range, below 300-mesh was determined by the pipette method, based on Stokes' Law. A small concentration of 'Calgon' (Sodium hexametaphosphate) was used as dispersal medium, and the residues were dried by means of infra-red radiation. The analyses, results of which are given in the table below, were carried out by Mr. T. G. Jones. A graphic comparison of results is shown by the histograms of Fig. 5.

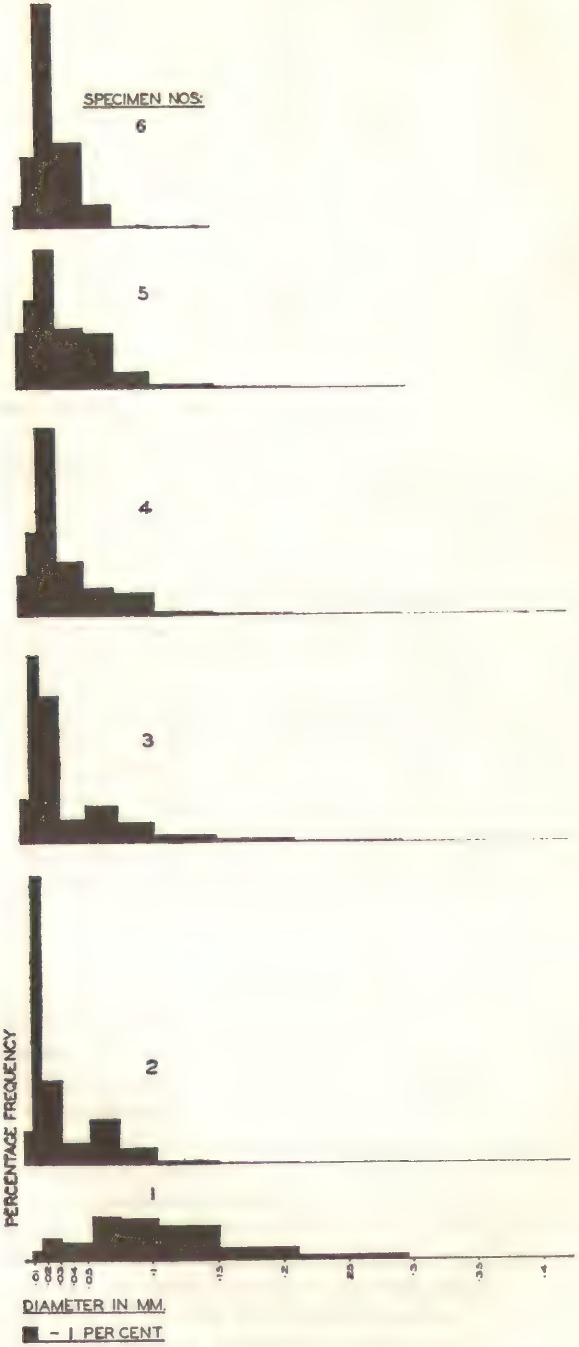


FIG. 5. *Histograms showing comparison of particle-size analyses of Brickearth deposits of the Chatham District with Loess from North Germany*

Particle-size Percentages

Figures are those for material retained on sieve.

Sieve No. (B.S.S.)	Aperture mm	1	2	3	4	5	6
36	·422	·4	4·7	1·1	·7	·4	·7
52	·296	1·9	1·9	1·3	·9	·4	·2
72	·211	5·6	2·0	1·5	1·1	·7	·1
100	·152	12·0	2·9	2·2	1·3	1·4	·1
150	·104	33·2	3·8	4·6	1·6	2·2	·2
200	·076	14·9	6·4	6·7	8·4	5·7	·5
300	·053	17·5	13·0	13·9	10·7	21·2	8·6
Sub-sieve sizes mm							
	·053—·031	6·5	7·3	7·0	16·4	18·4	26·1
	·031—·016	5·9	20·0	34·2	43·7	32·1	51·8
	·016—·008	1·2	33·6	21·8	9·6	10·3	8·2
	·008—·001	·5	3·9	5·2	4·8	6·8	2·3
	Less than ·001	·4	·5	·5	·8	·4	1·2
		100	100	100	100	100	100

1. Face of disused brickpit, 1 mile N.E. of Sittingbourne Station.
2. Lower Brickearth, beside Cuxton road, W. of Temple Marsh.
3. Old brickyard at Hoo.
4. Upper red-brown columnar brickearth Cuxton brickworks.
5. Old brickearth pit at Hoo.
6. Loess, near Scharfeld quarry, near Bad Lauterberg, Germany.’

Dr. J. Phemister, who carried out a petrographical examination of brickearth from Mere Court Brickworks, Murston, near Sittingbourne, reports that about half the sample passed the 180-mesh sieve (0·09 mm). The fine material consists predominantly of quartz in angular grains, with subordinate orthoclase, microcline and sodic plagioclase, some carbonate and a little muscovite. Minor constituents identified include gypsum, epidote, zircon, tourmaline, glauconite, rutile, augite, hypersthene, hornblende, chlorite, garnet, ?talc, ?scapolite, ?corundum. In material coarser than 100-mesh (i.e. 0·17 mm) the quartz grains on the whole are subangular, but occasional well-rounded grains were noted. Ferruginous aggregate, in part carbonate, occurs in the coarser material, and some of the quartz is turbid and yellow (E. 17590–3).[1]

H.G.D., S.C.A.H.

DETAILS

Brickearth occurs along the valley of the Medway from Wouldham to Lower Stoke, the most extensive spreads being on the western banks. The higher patches are in the main of solifluction origin, and, while those on the lower slopes of the valley were to a large extent laid down in water, they are almost invariably overlain by deposits of the former type.

A stretch of brickearth bordering the alluvium of the Medway from near Wouldham Church to near Rings Hill Farm, passes into more variable chalky loams, gravels and rubbly hillwash at its northern and southern ends. It is itself somewhat chalky and contains loam and sand, subangular and angular flints, well-rounded lumps of chert and ironstone derived from the Lower Greensand and a few Tertiary pebbles. A section 250 yd south-south-west of Starkey Castle Farm in a cutting connected with an adjacent disused chalk-pit showed the drift increasing north-westwards downhill from a thin chalky soil and rubble to more than 10 ft of fine brickearth, at the top more flinty, loamy and chalky than below, the whole being rather crudely bedded. There is no distinct demarcation between head and river brickearth.

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[1] Numbers in brackets refer to mounted preparations, registered in the Sliced Rock Collection of the Institute of Geological Sciences.

Beneath the deposit of hillwash extending along the riverside past Borstal, both gravels and brickearths occur. Cook (1914, p. 221 and pl. xxi, fig.3) describing the Borstal area, notes that the brickearth hereabouts is sandy, with flints and pebbles, except nearer the river, and records mollusca and flint flakes as at Halling ('Halling Man' site, *see below*) as well as *Elephas primigenius*, *Rhinoceros tichorhinus*, *Cervus* and *Equus*. Both head and river brickearths were seen to a combined depth of 20 ft in the cutting leading to the river from the chalk-pit 300 yd north-west of Borstal Church, varying from sandy brickearth to current-bedded calcareous loam, and banked steeply against the Chalk. The upper part is a brown head brickearth with columnar structure; flints occur in both beds, the river deposit locally being gravelly at the top and containing ironstone, chert and pellets of chalk. About 30 ft of the sandy brickearth resting on gravel of the Low Terrace was recorded by Hughes. This exposure, a little south of Borstal, is recorded by Cook with a section which shows the variability of the river deposits, their distinction from the overlying head and the passage into head of the deposits trailing off the Chalk slope.

The narrow strip of hillwash bordering the river towards Rochester also conceals some brickearth as well as gravels of the Low Terrace (*see* p. 142). Cook records a section formerly seen a quarter of a mile south of Rochester Castle in which brickearth with chalk pellets, small angular flints and some pebbles alternated with sandy beds; the whole being capped by a dark red clay head. A pocket of head containing many land mollusca appeared to have accumulated in an old stream channel.

On the west bank of the Medway a spread of loamy and chalky brickearth, passing on the west side into rubbly hillwash, extends from New Town, Halling, as far as Cuxton Church. Southwards past Halling the drift also includes a good deal of brickearth which has not, however, been separated from the hillwash. About 80 yd east-north-east of Halling Station an excavation which yielded a burial skeleton ('Halling Man') exposed, beneath the head and overlying the gravel and sand of the Low Terrace of the Medway, two beds of brickearth and a capping of sand. Holocene and Pleistocene bones and land shells were present and ?Early Mesolithic flint flakes, formerly assigned to Aurignacian (Oakley, K. P., *in* Kerney 1963, pp. 250–1). These, and the presence of fire hearths, indicate old land surfaces, and show that the deposit is essentially of head origin, parts of which may have been modified into a bedded series by water.

A cutting, about 680 yd north-north-west of Halling Station, connecting the quarry with the Cement Works, exposed chalky head on the south-west (p. 127) passing into fine brown and buff chalky brickearth, 6 ft to 10 ft, overlying similar drift with angular and unworn nodular flints and pellets of chalk. In the railway-cutting opposite Whorns Place, about 15 ft of chalky brickearth with flinty seams were seen to overlie fine buff brickearth exposed for about 5 ft. Hughes recorded about 20 ft of brickearth with *Succinea* and *Valvata ?*.

The Chalk spur on the north side of the Cuxton valley opposite Court Lodge carries a small patch of fine head brickearth, partly flinty and chalky and seen to a depth of 5 ft in an old pit. Bennett (1904, p. 463) mentions a pit which is probably the same one while Hughes recorded 8 ft of a red-brown loam with scattered flints, on gravel which was considered to be overlapped by the brickearth.

The patch extending along the left bank of the Medway north-eastwards from Cuxton is divided into two by a small head-filled valley. The south-western part consists of bedded chalky brickearth with flints which passes indefinitely into the flinty chalk rubble and loam which extends up the Cuxton valley. At Cuxton Station a 30-ft well (272/130) apparently penetrated the deposit, described as a clayey loam, chalky at the top. The eastern part was worked at the Cuxton brickfield, about half a mile north-east of the village; Hughes saw a section in a brickfield at Cuxton where a sandy bed with unworn gravel, about 12 ft thick beneath clayey soil, overlay fine brown loam, with a few broken flints, passing into chalk rubble and banked up against the Chalk.

S.C.A.H.

A sunk track at the entrance to a chalk-pit (*see* p. 40) higher up the valley slope exposes the following section in this spread; the various layers slope gently towards the river:

	Ft
Red-brown coarse brickearth with a few scattered stones, mostly patinated white	4
Pale buff gravel with some pebbles of chalk, sharp, fresh flints, some patinated white and others ochreous, also some Tertiary pebbles and ironstone	3
Very fine, pale yellowish buff brickearth with some scattered chalk pellets and, here and there, angular, white flints, especially in the lower part	8
Coarse gravel with large white and buff flints and lumps of chalk	4
Chalk with large flints	–

A Pleistocene molluscan fauna has been recorded by A. S. Kennard in MS. from this locality (Snuff Box Pit).

An adjacent well-boring (272/28) proved 26 ft of brickearth resting on gravel of the Low Terrace (*see* p. 143); the bottom 5 ft, being soft and sandy, may be river brickearth.

At the cement works, west of Temple Marsh, a small spread of brickearth lies partly on Chalk and partly on the landward side of a patch of low terrace gravel. Near the southern end of this spread 5 ft of pinkish buff loam rest on rubbly chalk and that on undisturbed chalk, and about 100 yd farther north-east a section showed 6 ft to 7 ft of buff loam, rather stony, with a gravel of chalk rubble and flints at the base, resting on chalk. At the northern end of the spread a small pit exposed, in 1937, 3 ft of orange-brown loam with columnar structure and containing streaks of scattered small flint chips, resting with sharp junction on 5 ft of pale, biscuit-coloured brickearth with scattered sharply-angular flints and pellets of chalk.

South of Strood a long spread on the left bank of the Medway, extending northwards from Temple Marsh to north of Strood railway station, has been extensively worked. Old pits north of Rose Cottage show up to 20 ft of brickearth, and in 1937 a section 200 yd west by north of the farm consisted of 8 ft to 10 ft of dark buff-brown, harsh and rough brickearth, with columnar structure and containing scattered flints and chalk pellets, resting on 10 ft to 12 ft of fine, buff-yellow, rather sandy brickearth, with chalk pellets and small flint chips here and there. The sharp line of demarcation between these two beds falls irregularly eastwards towards the river. The base of the brickearth and the underlying chalk gravel resting on chalk are exposed in the railway-cutting immediately west of the section. Hughes described the two layers of brickearth seen in this pit, noting that the higher one seemed to be derived directly from the wash of the adjoining higher ground, but whether it was deposited under water or sub-aerially was not clear. He also stated that gravel below the brickearth, containing lumps of chalk, was worked to a depth of 15 ft at the northern end of the pit and to 5 ft at the southern end. At the sports ground, about half a mile north-north-east of Rose Cottage, the brickearth is only 2 ft to 4 ft thick covering gravel.

North of Strood railway station, much ground has been excavated at the railway yards at the tunnel entrance. A section on the south-west side of the line, 300 yd north of the station, showed 10 ft of sandy, yellow brickearth with streaks of chalk pellets, resting on and banked against steeply rising chalk to the west. Whitaker saw 25 ft of brickearth hereabouts in 1862, the junction with the chalk being irregular, marked by a bed consisting almost wholly of chalk rubble with, here and there, a flint pebble. There were also irregular masses of gravel in the brickearth and over the whole there was, in great part, a brown loam with flints (rainwash) at one spot 12 ft thick. The brickearth below the loam was evenly bedded, with small rounded pieces of chalk (perhaps the average size of a pea) arranged in beds and with a few lines of hard race nodules in the lines of bedding. From the middle part of the deposit were obtained *Bythinia*, *Lymnaea palustris* (Müller), *Planorbis*, *Pupa* and *Succinea*, the last very common. A little west of the tunnel and high up in the face of the excavation, there is a small valley eroded in the chalk and filled with brickearth.

Small patches of brickearth occur here and there on the valley slopes west and south-west of Strood. Exposures in foundations of houses, pipe trenches and so on of a new building estate (1937), showed 4 ft to 5 ft of dark, buff-brown loam resting on paler loam seen, in the centre of the valley, to a depth of 15 ft, without the bottom having been reached (*see also* p. 131).

North of Frindsbury a spread of brickearth at 120 ft to 130 ft O.D., from 2 ft to 4 ft thick, has been worked together with 10 ft to 15 ft of the underlying Thanet Sand. At the foot of the slopes and bordering the west side of the small stream that flows from south of Haven Street to join the Medway east of Frindsbury, are thin but extensive spreads. Old pits, mostly overgrown, are 3 ft to 4 ft deep but one section, 500 yd east of Frindsbury Church, and on the side away from the stream, showed 12 ft of brickearth resting on chalk. These deposits lying at 25 ft to 30 ft O.D., are largely of resorted Thanet Beds and have a fairly high stone content.

The ridge of ground between this stream and the Medway is composed of Thanet Beds. On its eastern side it forms a subdued cliff feature of the river, and it is capped by a spread of brickearth overlying gravel. The elevation of this spread varies from place to place, surface levels being over 50 ft O.D. on the south, 40 ft near the middle and 67 ft at the northern end. As pointed out by G. E. Hutchings (1925, p. 419) the gravel here, though extending parallel with the Medway, does not constitute a terrace of the present valley, but appears to occupy the bed of an abandoned course of the river. The overlying brickearth varies considerably from place to place in the many sections made in the course of excavations for military practice. At least 10 ft thick, it reaches 25 ft at a well 320 yd west-north-west of the Castle, while Whitaker and Hughes described a section showing 29½ ft of drift, exposed in 1862, north-west of the Castle as follows:

	Ft
Chocolate-brown, clayey brickearth (like reconstructed London Clay) with lighter-coloured sandy layers	7
Loose gritty sand with dark grains (like reconstructed Woolwich Beds) ..	3
Irregular gravel with sand lenticles	3½
Loam with scattered stones, layers of mottled clay and wisps of sand ..	8½
Chocolate-brown clay	1½
Loose, gritty, yellow sand with dark grains	1
Gravel with bunches of small black flint pebbles at base (like 'bottom bed' of the Woolwich Beds)	5
Thanet Beds	seen to 9

It seems clear that this deposit is in part derived from the local Tertiary outcrops and also that it was, in part, laid down under water.

The most extensive brickearth deposits in the Medway valley border the west bank of the river for a distance of about 3 miles, from Hoo to North Street, with an average width of about three-quarters of a mile. These rest on low terrace gravel near the river, and on London Clay on the landward side, the surface levels rising gently from about 20 ft O.D. near the alluvium to over 100 ft due north of Hoo. Much of the lower part of these spreads appears to have been laid down in water and is classed as river-brickearth but the more elevated parts are of solifluction origin and there is a superficial layer of this type covering most of the spread.

Brickearth has been excavated from a considerable area south of Hoo and in 1938 a face about 500 yd south-west of Hoo Church showed 4 ft to 5 ft of red-brown brickearth on 4 ft to 5 ft of bedded yellow sand with ½-in to 1-in streaks of white clay exhibiting rootlet holes; this latter passed down into evenly-bedded sand and gravel, seen for 10 ft. Another section, 300 yd north of this, exposed a soil composed of 1½ ft of grey-brown silty loam with stones, resting on 9 in of red-brown stony loam and 2 ft of dark red-brown brickearth with columnar structure, separated by an irregular gravelly seam up to 1 ft thick from the underlying pale, yellow-brown sandy valley brickearth with rootlet holes. At 600 yd west-north-west of the church 3 ft of dark red-brown columnar brickearth with scattered stones rest on 3 ft of pale brown to buff brickearth with no stones but small race concretions. The upper bed shows faint colour banding suggestive of bedding but this may be due to leaching by meteoric waters at soil water-tables. In 1937, a temporary section 200 yd north of this exposed 1½ ft of grey-brown, loamy soil on 1½ ft of red-brown clayey brickearth with columnar structure, resembling redeposited London Clay, separated by 3 ft of irregular gravel with rafts of clayey brickearth like that above, from rather sandy yellowish buff brickearth below.

A large excavation north of Hoo High Street extends nearly up to the 100-ft contour. The pit, long since disused, was active when visited by Whitaker in 1862, who records having seen more than 40 ft of brickearth and was informed that a thickness of 52 ft had been proved. Some of the deeper parts of the pit enter the London Clay, the surface of which seems to be irregular for he noted that it 'rises up in a sort of pinnacle' in the tramway cutting, just north of the High Street. Whitaker also noted the darker brown colour of the upper part of the deposit, which contained a few broken layers of flints and pebbles, some of which were lenticular, showing a dip of 15° S. towards the river, as well as the more sandy lower part, which showed evidence of fine bedding, dipping 2° to 3° N. In 1938 the pit was much obscured, but the west side showed 10 ft of dark-brown, coarsely-sandy brickearth with stones, scattered in the upper part but in bunches below, resting on 5 ft (seen) of yellow silty brickearth, while on the east side, the top 8 ft of the face were hidden, but below, to the north, were 6 ft of yellow brickearth with a horizontal streak of stones, largely cherts, about the middle. This terminated southwards in a steep bank against which was coarsely sandy, red-brown brickearth with scattered stones and gravelly at the base, the structure of which strongly suggested the slumping of a sludge deposit over the bank of yellow brickearth. In the area south-east of Hoo the brickearth appears to be not more than 4 ft thick, all of the red-brown type and to rest directly on gravel.

An exposure in a disused railway-cutting, 1½ miles east by north of Hoo, is about 15 ft deep, and much overgrown, but where it passes under the road just east of Beluncle, the deposit appears to consist of about 4 ft of sandy brown loam with bunches of stones here and there, on pale grey and ochreous laminated silty clay, apparently a bedded brickearth. Farther south in the cutting this lower part seems to have intercalated thin seams of yellow sand. London Clay is exposed in the bottom of the cutting 600 yd south-east of Beluncle.

At North Street the road-side banks west of the village showed 8 ft of yellow-buff brickearth, pocketed by an overlying red-brown, coarsely sandy brickearth with bunches of stones. A very small patch of buff brickearth east of the village is only exposed in the shallow railway-cutting.

At Lower Stoke, south of Allhallows, surface indications show that the brickearth may here be only a thin layer over gravel. Towards the river, however, the railway-cutting, though much overgrown, gives the following section which appears to represent a superficial sludge deposit on a brickearth that has suffered much sorting by river action:

	Ft
Brown, sandy clay with columnar structure and a few small scattered stones	4
Greyish, brownish and white fine silty clay with dicey structure, containing much powdery and nodular race	½
Medium grade yellow sand without stones	½
Lilac and smoky, silty clay with dicey structure and race nodules ..	½
Medium grade yellow sand with stones seen to	4

The only occurrence of brickearth in the Thames valley is that on the Essex bank of the river at East Tilbury. Bordering the alluvium it is up to 8 ft or more thick and consists of rather sandy loam with pellets of chalk and scattered small flint chips. H.G.D.

The tongue of head-brickearth in the Luton valley south-east of Chatham passes very gradually into stony loams and chalky rubble of hillwash origin which border it on all sides. In the northern, built-up part of the valley brickearth was formerly worked. From early descriptions there is evidence for the occurrence of brickearth together with gravel, beneath the general flinty loam in that part of the valley around Luton Church. G. E. Hutchings (1925, p. 427) describes the Luton valley drift as being alluvial detritus consisting mainly of red clay with nodular and broken flints derived from the Chalk plateau.

The drift was formerly dug at a brickfield westward of the church, and was being worked in 1938 at the north-west of Darland, where fine brickearth, containing tiny pieces of chalk and only very few small white chips of flint, was seen to a depth of 6 ft, but on the south side the deposit showed flinty patches and near the road old workings exposed 4 ft to 10 ft of brickearth, with flints crowded at the bottom, resting irregularly on the Chalk. Turner (1928, p. 301) refers to the remains of *Bos*, *Cervus* and *Elephas primigenius* from the Luton valley brickearths. Good brickearth probably dies out just east of Darland, being replaced by extensive hillwash trailing down mainly from the slope on the southern side of the Speeks Bottom valley.

Hughes described gravels and brickearths of the Luton valley in some detail, stressing the probable rainwash origin of the greater part of the brickearths. The admixture of chalk apparently derived mainly via the chalky head on the north, and of flints mainly from the flinty loams on the south, points to the probable origin of the deposit as one of sorting of the finer materials from the Head, very probably assisted by water locally, but the deposit is clearly not truly fluviatile. S.C.A.H.

Sections in brickearth varying from 3 ft to 6 ft in depth were noted in a spread bordering the Medway at Gillingham, and again at Horsham Marsh, west of Upchurch. In the former district much has been worked off, and the area is now largely built over. S.B.

Near Hartlip an important brickearth deposit occurs in the valley and on the adjacent high ground and continues westwards from Moor Street. On the higher ground south of Upchurch, as far as the Watling Street, the deposit contains much angular to subangular gravel, especially in the bottom of the valley and on the flanks of the hill at Upchurch, where a high proportion of stones has rendered it uneconomic to work.

On the high ground east and south-east of Upchurch the best brickearth has been removed; no trace of the pit faces are now visible. Near the alluvium 200 yd north-east of Wetham Green, in the south face of a small pit, about 3 ft of a rather poor-quality brickearth overlie sand with shells. South of Frog Farm, half a mile east-north-east of Upchurch, a small pit has been dug in 6 ft of brownish brickearth; there is no gravel at the base although 300 yd to the west brickearth is more or less replaced by gravel.

North of Moor Street practically the whole of the brickearth has been removed; south of Watling Street it extends for an average of 500 yd southward. In this district few flints occur throughout the deposit and only towards Gore House does gravel come in at the base. West of Otterham Quay are several small patches, up to 6 ft thick, of brown-coloured brickearth. It appears to have been thin at Vineyard Chalk Pit north of Moor Street but towards Otterham Quay it was at least 5 ft thick, a somewhat sandy silt, buff to brown in colour. About 500 yd east of Moor Street and on the north side of the railway an exposure showed up to 15 ft of buff brickearth, while 400 yd west of Gore House a pit face showed 3 ft of gravelly brickearth with sarsens overlying Thanet Beds, and 150 yd south of this pit 2 ft of gravelly brickearth rest on 4 ft of sandy brickearth with Thanet Beds below. On the north and north-west slopes of the high ground north of Gore House brickearth averages 7 ft in thickness and contains few flints, but near the top of the hill sarsens presumably derived from the sandstone of the local Woolwich Beds were seen.

West of Newington brickearth has been extensively dug north-west and south-east of Breach. To the north-west good quality brickearth, buff to brown in colour, has been dug to a depth of 10 ft, the average being about 6 ft. Flints occur scattered throughout the deposit and lenses of gravel are present at the base. South-east of Breach the digging has been more sporadic and brickearth has been exposed to a depth of 5 ft. Though the percentage of flints scattered throughout shows no marked increase over the above, the bed of gravel at the base is thicker and is more or less continuous. The brickearth is banked up against the Woolwich Beds of the outlier half a mile north-west of Newington and one pit extending a considerable distance up the side of the hill exposed brickearth resting on Thanet Beds and on Woolwich Beds. In one part of this pit the brickearth contains shells derived from the underlying Woolwich Beds; in another section it passes gradually into the solid. Near the railway the gravel has also been dug. South of Watling Street on both sides of the Hartlip Road are large shallow pits; exposures show gravel to a depth of at least 5 ft, the brickearth being absent in places and only a foot or so thick where present. In the only pit in this patch of brickearth south of Watling Street, 400 yd west-south-west of Pond Farm, are seen differences of thickness from 4 ft on the west face to 10 ft on the east face 200 yd distant. In the south-east corner of the pit brownish brickearth overlies laminated sand with occasional flints and thin bands of pebbles over loamy clay and sand, the pebbles probably derived from a small outlier of Woolwich Beds on Standard Hill to the south-east. The laminated sand, which is present in a lenticular-shaped mass wedging out to the west and north, indicates the influence of a certain amount of water in its deposition.

Between Newington and Lower Halstow the most northerly third of the original brickearth spread has been dug and exposures indicate a somewhat more sandy brickearth up to 6 ft thick but averaging about 3½ ft. Continuous with this is the brickearth extending from Bog Farm, Newington, to the marshes east of Lower Halstow, which fills a shallow valley. The deposit is banked up against the south-west side of Callum Hill at Hawes Wood, where a pit has been dug in a somewhat clayey brickearth up to 10 ft thick. It becomes thinner about 300 yd south of Elm Farm where angular flint gravel comes to surface.

Resting on a somewhat steeply-inclined northern slope of the London Clay west of Iwade are two patches of brickearth whose position and fairly high argillaceous content suggest accumulation as a head deposit from London Clay.

The extensive, irregularly-shaped spread which covers the clay ground north of Bobbing, from Great Norwood eastward to the alluvium of the Swale, has so far been little dug, possibly since the brickearth is generally more argillaceous than that of the east. The deposit thickens and thins irregularly, the maximum thickness being probably only a little over 6 ft. Around Iwade brickearth up to 3 ft thick grades into the alluvium of the Swale. North-east of Great Norwood, however, it is a fine silt, proved up to 5 ft; the level surface of the ground suggests the former presence of water. The deposit rests on the uneven surface of the London Clay with comparatively few flints at the base except in one or two places near the margin, and a few flints are scattered throughout the brickearth. In a pit west of Pheasant Farm, north-east of the Bobbing–Sheerness Road, up to 6 ft of somewhat argillaceous brown brickearth have been exposed on the west face, and in 1946 Perryfield pit, a quarter of a mile west of Bobbing Church, showed a 7-ft section (Plate IVB). North of Kemsley a considerable amount of a more arenaceous brickearth has been dug, the maximum thickness being about 6 ft. North-west of the Paper Mill 6 ft of brown brickearth were noted.

In the valley through Stockbury brickearth occupies the wider part of the valley floor and covers much of the higher ground on either side. Much brickearth has been dug off west, east and north of Milton Regis, Sittingbourne, and in places gravel which underlies the brickearth has also been dug and the ground much disturbed especially immediately north-east of the railway junction.

The deposit is dug, along with sand (Thanet Sand) and chalk, in a pit 600 yd north-east of Borden Church where it varies from 3 ft to 12 ft in thickness and contains very few flints. The top surface is comparatively flat, the rapid variation in thickness being due to the uneven surface of the Chalk and the wedging out of the Thanet Sand.

A certain amount of brickearth has been dug around Key Street where it rests on gravel. A temporary section on the south side of Watling Street, 700 yd east of the junction with the Maidstone Road, showed 6 ft of brown brickearth on subangular flint gravel, and about a quarter of a mile west of this junction a road section on the Watling Street exposed brown brickearth containing pebbles, presumably from the nearby Blackheath Beds.

Most of the brickearth has been dug away near the railway junction at Sittingbourne and east of the railway as far north as Kemsley. In the triangle of railway lines at the junction a small exposure showed 6 ft of brickearth but the deposit thins to the east and is only a foot or two thick under the western part of Milton Regis. Between North Street and the railway a remaining patch exposed a face up to 8 ft; few flints are present. Around the church and northwards to Kemsley several remnants average 7 ft thick and in one place 12 ft of brownish brickearth were to be seen, containing few flints. From a large pit between the railway and Quinton Farm, Bobbing, the greater part of the best brickearth has been removed; the depth of the exposed face averages about 7 ft. Flints are relatively scarce as they are in a similar brickearth up to 8 ft thick exposed in an adjacent pit to the south-west.

Very little brickearth has been left on the Chalk around Sittingbourne but on the south several small patches remain. About 150 yd south-east of Chilton up to 6 ft of brown brickearth are exposed in a pit. A spread north of Tunstall has not yet been exploited.

In the valley south of Snipershall, east of Sittingbourne, brickearth has been partly removed. The deposit reached a maximum of about 4 ft. It is brownish in colour, contains some scattered flints and overlies a bed of subangular flint gravel. East of Rodmersham Green brickearth is up to 4 ft thick.

Several small patches in the Bapchild-Tonge-Murston district are all that remain of a large spread of best quality brickearth, which reached its maximum thickness of about 20 ft in the east. Spreads south-west of Bapchild and in the neighbourhood of Rodmersham, not yet worked, are up to 4 ft thick.

In the extensive spread between Bapchild and Teynham the brickearth is thin and gives place to gravel between the former village and the railway.

Representative of the numerous brickearth exposures in the Bapchild area are the following. In 1937 the brickearth workings extended to the road 500 yd west of Haywood Farm so that the south face is in Thanet Sand for half its length, which formation here is also worked. The depth of the face varies from 2 ft to 7 ft and the junction between drift and solid is indefinite in places. In 1927 (Dines 1927, p. 12) it was noted that the brickearth then exposed was divisible into a lower, sandy, and an upper, more clayey part, separated by a line of flints, but in 1937 this subdivision could no longer be seen. The north face of the pit, 330 yd north-west of Haywood, shows up to 10 ft of brickearth. The deposit is a sandy silt, light-brown in colour and towards the west is comparable with head from the Thanet Beds.

A cutting on the south side of Watling Street 200 yd north-west of Bapchild Church exposed 6 ft of brown brickearth.

A remnant of brickearth extending northwards from 400 yd north-east of Murston Church is divisible into an upper and lower part by a faint almost horizontal line of demarcation which may represent a bedding plane. It has been dug in two stages and very little remains of the top part which is a silt, brownish buff in colour and may be up to 4 ft thick. The lower part is more sandy, paler in colour, up to 12 ft thick, and shows faint traces of bedding and thus may have been to some extent deposited by water. Pockets of subangular flint gravel occur near the base, and about 100 yd to the south a bed of gravel at least a foot thick is seen overlying Thanet Beds. It was from somewhere in this area that Hughes recorded the following section from 'near the engine-house north-east of Murston':

		Ft
(*a*)	Brown and buff brickearth more sandy in places with flints scattered through it or collected into patches; of more uniform colour but showing streaks of bedding more distinctly along dip to north-east	20
(*b*)	An irregular bed of gravel at the base	1
(*c*)	Greenish and rusty sharp sand	½
(*d*)	Brickearth with *Pupa*, *Cyclas* and bones of Elephant, Rhinoceros, Horse and Ox	to 10
(*e*)	Gravelly at base with a few black pebbles as if from Tertiary pebble bed near.	
(*f*)	Grey green and rusty sand (Thanet Sand).	

The whole of the brickearth now exposed would be equivalent to bed (*a*) and the gravel at the base bed (*b*). No evidence of beds (*c*), (*d*) and (*e*) could be seen in 1937 but the ground has been much disturbed with the digging.

To the west of Tonge Church most of the brickearth has been dug off leaving remnants mainly under roads and buildings. The deposit varies from 2 ft to 9 ft in thickness and is a sandy silt, buff to brownish in colour and with occasional angular to subangular flints scattered throughout. Lenses of angular gravel up to 1 ft thick occur at, or more rarely just above, the base; towards the centre of the valley half a mile west of the church the thickness of the gravel increases.

About 800 yd north of Tonge Church exposures show a few feet of sandy silt with locally-derived pebbles.

West and north of Lynsted, in the area between the railway and the alluvium of the Swale, the brickearth has long since been dug away, while between the railway and Watling Street to the south, just over half the original spread remains. South of Watling Street it is worked at Little Dully. A chalk-pit 300 yd north of Sundries Farm, north of Lynsted, showed up to 7 ft of sandy loam, buff to brown in colour, resting on Chalk. Near or at the base of the brickearth is a 1-ft bed of angular flints with a few pebbles, above which angular flints are fairly numerously scattered throughout the deposit. A pit at Little Dully dug at the western margin of the spread, shows only 3 ft of brickearth near the farm, while the east face, 650 yd distant, exposes 10 ft. Flint implements believed to be of Aurignac culture were found in this deposit in 1927. Large pits between Watling Street and the railway show from 2 ft to 8 ft of sandy brickearth; the variation in thickness is due in great measure to the uneven surface of the Chalk. North of the railway, 150 yd east of Bax Farm, the face of an old pit shows up to 5 ft of a similar deposit and about 100 yd north-east of Teynham Station the thickness, as shown by the remnants of the original spread, is as much as 10 ft. The deposit thins against high ground of Woolwich Beds at Teynham Street and north of Bax.

Brickearth between Norton and Deerton Street varies in quality. It is generally of a buff colour, a little coarser grained than the best types and in places almost indistinguishable from some of the neighbouring hillwash. About Upper Newlands the brickearth is about 5 ft thick and at Watling Street it is 10 ft to 12 ft. In the west face of a chalk-pit 300 yd north-west of Upper Newlands, up to 3½ ft of buff-coloured loamy sand, with some Bullhead Bed flints at the base, rest on Chalk. At Deerton Street, brickearth and considerable quantities of Thanet Sand have been dug. An old pit a quarter of a mile to the north-west showed about 4½ ft of brickearth.

At Mockbeggar, in the west face of a chalk-pit between the road and the railway, are 4 ft of sandy loam. The material resembles hillwash from Thanet Beds and rests on 4½ ft of that formation. J.A.R.

HILLWASH HEAD

Several types of deposit usually of recent formation, which do not fall into specific lithological classes such as brickearth, gravel, etc., may be grouped under the term 'Hillwash Head'. They show great diversity in composition from almost pure chalk rubble to resorted Eocene material. The majority are comparatively thin washes resting on hill slopes and containing material either from the Clay-with-flints or from other head deposits, together with varying amounts of sand and clay from the Eocene Beds. They also occupy many of the valley bottoms of the area, where accumulations up to 30 ft thick may be present, and where they are the equivalents of part of the deposits shown on adjacent geological maps as 'Dry Valley Gravels'. These deposits have, in many places, an important bearing on the soil and agriculture, as for instance where loamy head covers the London Clay around Hoo and Allhallows, and where they rest on the Chalk.

Accounts of this drift have been given by Le Neve Foster and W. Topley (1865, p. 446) and by F. J. Bennett (1904, p. 463), and some of its characteristics were noted by Goodchild (1885, p. 151). Bennett referred to the 'Scarp Drift' and 'Residual Drift' of the Medway Valley above Cuxton. The accumulation of Head even at the present day is well illustrated in an account by G. E. Hutchings (1924, p. 64 and pl. iii, fig. 2) and the following description of conditions near Luddesdown is applicable to the Chalk area on both sides of the Medway. On the edges of the valleys, banks of flints occur on the border of the Clay-with flints and form terraces on the valley sides where arrested by vegetation or artificially, as by road-banks. Rainwash and soil 'creep' hasten the accumulation of the drift and tend to concentrate any loamy material available to form a heavy brickearth, with many flints, in the bottom of the valleys.

In some localities, especially in the Medway valley, the hillwash contains a considerable molluscan fauna which is of interest in determining the age of the deposits and the conditions under which they accumulated. Palaeontological evidence points to the presence of head of both Pleistocene and Holocene ages. According to this evidence, conditions during the deposition of both were not generally colder than the present day and the climate was damp, especially during Early Bronze Age times. The oldest of the deposits is not earlier than late Pleistocene. S.C.A.H.

DETAILS

In the Medway Valley above Rochester hillwash is strongly developed and variable in character, obscuring the solid formations to a considerable extent and covering, overlapping or grading into other drifts.

On the west side of the Medway, the drift about Horn Street and Ham Hill consists of loam and brickearth with flints, becoming more gravelly nearer the latter place, where river gravels are overlapped. Sections at the sand pits at Ham Hill (*see* p. 18) showed up to 14 ft of loam and variably chalky brickearth, with flinty seams, resting irregularly on Folkestone Beds, or here and there on intervening river gravels (p. 140). This spread contains large subangular white flints, small chips of flint, small chalk pellets and occasional Tertiary pebbles, Lower Greensand chert and boxstones. In some parts of the pits the drift is channelled deeply into the solid and contains only a few flints at the base: elsewhere the stony content is variably concentrated, but especially near the top and base of the deposit. Bordering the alluvium east of Ham Hill, 2 ft to 4 ft of flinty brickearth cap gravels of the 1st Terrace of river gravel (p. 144).

West of Snodland an outlying patch of chalky rubble on the Gault a third of a mile west of Rookery Farm is similar to that forming a tongue from Paddlesworth to Cox's Farm, which becomes clayey eastward and southward across the Gault. The main spread upon which Snodland stands is not a river gravel as thought by Topley (1875, p. 173), though gravels of the 1st and 2nd Terraces are locally present (*see* pp. 140–44). Topley appreciated nevertheless the presence of 'rain-wash' drift. It consists of chalky brickearth and gravelly loam, up to 15 ft thick in a well (272/78) 100 yd north-east of the station, passing northwards into a loamy chalky rubble with flints, 20 ft thick in a borehole at Holborough (272/128). The drift was well-exposed in the chalk workings at this place (p. 31), particularly on the east side. On the Gault to the south, gravelly loam and brickearth with chert, ironstone and tiny pieces of chalk, in thickness 1 ft to 7 ft, showed a northward change to 3 ft to 10 ft of chalky brickearth with flints at the base and land shells in the upper part. On the adjacent Lower Chalk the rubbly, loamy and gravelly drift showed much lateral variation, with crude lenticular bedding and festooning of coarse subangular gravel, but on the northern side of the quarry, nearest to Holborough, the drift, up to 6 ft thick, is essentially chalky.

Of the two tongues of drift north-west of Holborough, the southern one and the part where the northern one joins it consist of chalk rubble. The northern tongue is bordered by an old chalk quarry, and an extensive section a quarter of a mile north-east of Lad's Farm showed:

	Ft
Flinty loam	2
Chalky drift with few flints	2–6
Marly drift with pebbles and unworn flints	(seen) 6

At another point, 2 ft of brickearth with flints were seen to rest on 6 ft of chalky wash (*see* Plate IVA).

Kennard (*see* pp. 132–3) records Pleistocene mollusca from the section hereabouts ('Lee's Pit') but the topmost bed may be Holocene. North of Holborough the chalk rubble passes into chalky brickearth containing land shells, while the railway-cutting, and the tramway west-north-west to the chalk-pits, exposed up to 10 ft of loam and brickearth with variable chalk rubble and unworn flints, also chert and ironstone. Hughes noted 8 ft to 10 ft of brickearth and buff sand with beds of brown calcareous brecciated conglomerate made up of bits of chalk and flint and mentions the next chalk quarry cutting (350 yd west of Halling Church), where was seen an irregular deposit of coarse and fine sand interbedded with and passing at its north end into chalk rubble. In one place there is a hard sandy breccia of chalk, flint and ironstone, but much of the sand is bedded and occupies pockets beneath the loamy head; it has been distinguished from the latter as the relic of a spread of 2nd Terrace gravel (*see* p. 140). About 250 yd farther west-north-west the cutting divides a tongue of chalk rubble and showed 3 ft of buff chalk rubble with flints overlying 6 ft of fine white rubble with a flinty base resting on blocky chalk.

On the north-east chalk rubble merges with loamy drifts near Halling Station. A quarry section (Hilton's pit, p. 31), on the east side of the village of Upper Halling, showed buff chalk rubble drift, with a few flints 3 ft or 4 ft down, filling the valley bottom for a width of 60 yd, with a thickness of 22 ft in the middle. Kennard (p. 132) records land mollusca, assigning 12 ft of the drift to Holocene and 10 ft to Pleistocene. At a higher level on the south-east flank of this valley is a bank of 3 ft to 10 ft of chalky drift with flints, chert and pieces of ironstone.

Hillwash overlying river deposits on the east side of Halling is recorded in the detailed section given by Cook and Killick (1924, p. 150; Cook 1914 and 1923) at the site of the 'Halling Man' discovery (p. 115). Beneath a layer of humus, a dark red loam, with a few scattered flints at the top but many flints and concentrations of land shells in channels at the base, was seen to overlie irregularly a buff brickearth with unbroken flints, the whole of the beds occupying together about 4 ft. The last bed contains many chalk pellets, some small angular flints, Lower Greensand debris and Eocene pebbles. Many of the large flints appeared to retain disintegrated traces of their original chalk matrix. The shells in the channels of red loam are of Pleistocene age as are the beds below the Head.

On the hill a quarter of a mile north-west of Halling Station there are pockets of flinty drift with chert and ironstone (Southern Drift of Bennett 1904, p. 465) and a bank of downwash of this material on the eastern slope.

Northwards of this hill an extensive spread of hillwash mantles the valley slopes from above the Pilgrims' Road and merges with the brickearth bordering the Medway, beginning as a tongue of flinty chalk rubble above Upper Halling but becoming more loamy and variable eastwards. About half a mile north-west of Halling Station a section in the chalk quarry (Batchelor's or Formby's Pit of Kennard, p. 132) showed 2 ft of flint and chalk rubble resting on 4 ft to 8 ft of chalky drift with loam and nodular flints. A section in the tramway cutting about 680 yd N.N.W. of Halling Station showed on the south-west, near the quarry:

	Ft
Brown, chalky rubble with white flints	1 to 2
Buff, chalky wash without debris	1 to 6
Coarse nodular-flint 'gravel', with a matrix of chalky loam, lenticular and alternating with pale chalky wash	12 to 17

Kennard (1944, p. 129) records Pleistocene mollusca here. With the passage into brickearth bedding becomes more evident but a reference by Dibley (1899–1900, p. 250) to underlying 'valley gravel' probably only applied to lenticular gravel within the Head. Bennett (1904, p. 465) refers to nearly 40 ft of chalky 'Scarp Drift', with lenticular flinty beds and loam, and mentions a former section nearer the railway which showed the passage eastwards into loam (i.e. Brickearth). A borehole (272/12b) just south-east of the cutting, passed through 4½ ft of made ground and then 35 ft of drift on the Lower Chalk. Stones were recorded in the lower part and it is uncertain whether 'large sand and ballast' in the bottom 9½ ft should be referred to the head or to Low Terrace gravels.

The drift cut by the large chalk quarry at Whorns Place, Cuxton, remains only as small patches, which include pockets and banks of chalky rubble with unworn flints, crudely bedded with the hill-slope and about 10 ft thick, including a brown layer at the top (*see* p. 132). North-east of the quarry partly loamy rubble, 4 ft to 8 ft thick, is nearly separated from the adjacent brickearth by the cutting of the main road. The gravelly loam with ironstone on the hill west of Cuxton Church trails down from the contiguous patch of Clay-with-flints. It contains Tertiary pebbles and sandstone from the Wealden, and was noted as 'Southern Drift' by Bennett (1904, p. 464).

The Cuxton valley and its southern tributaries are occupied by hillwash head which varies from chalk rubble to loam and gravel. Just west of Cuxton the southern valley-side carries chalky loam and rubble in an almost continuous spread, whereas on the north side the drift is a very flinty chalk rubble practically confined to the valley bottom. Westwards past Lower and Upper Bush the drift is a very stony loam, westward of which again the valley contains loam and angular gravel with pebbles and chalk pellets. It is continuous with the deposit mapped as 'Dry Valley Gravel' in the adjacent Dartford area, and also grades up the slopes southwards into a thin spread of loam with flints. In the valley bottom half a mile west-south-west of Lower Bush, wells (272/129) proved 18 ft of drift, predominantly gravel with sandy clay, chalky in the bottom 3 ft. Hughes found that it is not easy to determine where the gravel line should be drawn, as the Clay-with-flints passes down in the hollows into a kind of gravel which is merely the Clay-with-flints with the clay washed out and this works down the valley and passes into the river gravels. He records a section in a gravel pit between Court Lodge and Cuxton showing 12 ft of rough gravel with sand and chalk, underlain by chalk rubble and overlain by 2 ft to 3 ft of surface soil.

Of the valleys south of the Cuxton valley, the Bush valley, west of North Wood, contains mainly loam with unworn flints and some chalk, while the

Dean Farm valley has Clay-with-flints downwash at its head separated from a narrow tongue of flinty clay and loam which soon passes into flinty chalk rubble and light loam. The latter especially mantles the west side of the valley, forming a light chalky brickearth near the Farm which materially alters and enriches the soil.

The Cuxton valley receives on its north side a narrow tongue of chalky hillwash which occupies the tributary valley south-west of Ranscombe. Other tongues of the head, in places gravelly, merge with brickearth north-east of Cuxton (*see* p. 116).

On the opposite side of the Medway, hillwash 4 ft to 5 ft thick, covering gravels and brickearth, extends from Rochester towards Borstal.

A hillwash spread west of Borstal (p. 115) varies from red clay to angular gravel; 4 ft of brown loam with chips of white flint were exposed in the cutting leading to the river from the chalk-pit 300 yd north-west of Borstal Church. Hughes described this bed as being very sandy in places, thinning out to the south-east and partly underlain by sandy chalk gravel with angular flints. In the north-west face of the chalk-pit half a mile west-south-west of Borstal Church rubbly chalk drift with flints, 10 ft thick in one part, fades out to zero up the slope of the hill.

South of Borstal flinty chalky loam from the Nashenden valley joins the spread of chalky loam with variable angular flint gravel which mantles the hill-slopes east of Wouldham Marshes, overlapping patches of 2nd and 3rd Terrace gravel and grading into brickearth near Rings Hill Farm (p. 114). Trimmer (1853, p. 290) described 15 ft of drift in an old pit hereabouts, the upper part consisting of ferruginous clayey loam with angular flints, passing occasionally into masses of angular flint-gravel in a clayey matrix; the lower portion being a white flint gravel with chalk, chert, sandstone and Tertiary pebbles. Hughes also referred to gravel and sandy brickearth formerly dug east of Rings Farm (i.e. Rings Hill Farm) and his description indicates that the deposits are continuous with chalk rubble, chalky gravel and gravelly rainwash. He describes a patch of river gravel, now placed with the 3rd Terrace, as being mixed with and passing into rainwash clay with flints; the head here is only 2 ft or 3 ft thick, however, as seen in the adjacent chalk-pit, and is essentially an unsorted chalk rubble or loam with flints and some chert and ironstone. Solution pipes in the pit contain coarse sand and gravel, probably derived from the river gravels, in addition to chalky loam and clayey brickearth with large subangular flints.

East of Wouldham the drift fanning out from the escarpment coombes is a chalk rubble. Many white flints were noted west of Ringshill Place. North of the church the rubble passes into loam and brickearth before the river is reached on the west, but southwards it directly borders the alluvium. The section at the disused Schoolfarm Lime Works, half a mile south-east of Wouldham Church, showed 9 ft to 12 ft of coarse unsorted rubbly chalk drift, with large irregular flints, chips of flint and some brown subangular flints ('Scarp Drift' of Bennett). Similar chalky loam and rubble, up to 10 ft thick, with predominantly white flints, is cut by the large chalk workings east of Wouldham Hall. It is very crudely bedded but a brown top bed is usually distinct from marly pocket drift below (*see* Whitaker 1872, p. 27).

South of Wouldham a section in the road-bank just south-east of Scarborough showed 6 ft to 10 ft of chalky drift with flints and land shells. Where the head reaches the Medway a quarter of a mile south of Wouldham Hall, it overlies sand apparently part of a small patch of Low Terrace gravel. Bennett recorded 18 ft of chalky drift with sand and flints (containing Mammoth, etc.) resting on fine sand devoid of any chalky drift, and also a small section hereabouts where his 'Southern Drift', containing Wealden sandstone, underlay chalky drift. Cook (1914, p. 222) noted a sand working near Wouldham Hall Cement Works (possibly the first of Bennett's sections) where sand and brickearth were capped by red ochreous angular flint gravel with clayey constituents. *Elephas primigenius*, *Rhinoceros tichorhinus*, *Cervus*, *Equus*, *Bos*, etc., are recorded.

In the chalk-pit about a quarter of a mile west-north-west of the church at Burham village, chalky drift with shells pockets the Lower Chalk to a depth of 20 ft. Up to 10 ft of similar shelly chalk downwash with flints were also seen in a road section south-east of Burham. Passing from the Chalk to the Gault, the hillwash becomes marly and clayey, with flints and chalk, and in the clay pits by the Burham Cement Works it consists of 2 ft to 4 ft of sandy loam with chalk, clay and flints, deeper locally in pockets.

Drift in the escarpment coombes around Bluebell Hill is typically a fine pellety chalk wash (or powdery chalk loam) with flints, crudely stratified with the hill slope and often pockety. The average thickness is some 8 ft to 10 ft but it tends to become thinner and more flinty and loamy south-west across the Burham road. In the large working in the Lower Chalk east of Great Culand, chalky drift with flints is up to 12 ft thick on the south-east side; other constituents are hard chalk nodules, pyrite, Tertiary sarsens and pebbles, and chert and ragstone from the Lower Greensand. Much of the drift can be separated as an upper brown chalky loam (with flints frequently crowded at the base) over a pale chalky wash (*see* Dibley 1918, p. 77; 1922, p. 75).

About 300 yd south of the cross-roads at Bluebell Hill a small exposure showed 8 ft of chalky drift crudely bedded with the hill-slope. Up to 4 ft of gravelly loam with chalk and sarsens were seen at the southern end of Eccles, and up to 6 ft of shelly chalk drift with flints and sarsens occur south of the Pilgrims Road.

Eastward of the Medway Valley hillwash is still extensive. In the Luton valley (*see* p. 120) contrasted types may be distinguished, and there is a general tendency for the drift to be distributed more particularly on the south and west sides of the valleys, possibly resulting from local climatic conditions.

Near Nashenden Farm a fairly broad spread of drift consisting of chalk rubble on the east merges into flinty loam from the west side. Four tributary valleys on the west contribute chalk rubble but three in Bridge Woods have narrow tongues of loam with flints and chalk. The eastern and steeper side of the valley continues to carry chalk rubble towards the bottom, but in the floor and on the west side, in the part of the valley southward of Fort Bridgewoods, the drift is a rich brown loam with flints.

A temporary section a quarter of a mile east of Borstal Fort proved 5 ft to 6 ft of flinty loam. Near Chatham Station loam and brickearth are associated with chalky wash, and Dr. Buchan has recorded a temporary section about 100 yd south-west of the station showing 6 ft of chalk rubble overlying brickearth seen to 4 ft. In the tongue of hillwash head cut by the railway where it emerges from the tunnel east of the station, as much as 20 ft of loam rest on the Chalk. In this neighbourhood the loam contains unworn white-coated flints and a few Tertiary pebbles. Just south of the cutting a temporary section showed 4 ft of chalky loam passing down into dark brown loam seen for 6 ft. About 300 yd north-east of the railway a well-boring (272/8) reached the Chalk at a depth of 32 ft; part of the overlying material is made ground, but the bottom 14 ft at least indicate chalky and gravelly drift. About three-quarters of a mile north-west of Snodhurst a small area of loam and brickearth borders the Clay-with-flints; a temporary section showed 5 ft of head, flinty at the top.

At Snodhurst, the road-cutting on the south side of the valley exposed brown loam and clay with broken flints and a basal bed with pellets of chalk, the whole seen to 5 ft. This flinty loam continues on the south side of the valley but chalk rubble predominates on the north, some half a mile further north-east, except where a tributary valley from the south contributes light loam and brickearth with flints and chalk. Similar deposits are found in Walderslade Bottom and the valleys eastward.

With the change in direction to a north-westerly trend the main Luton valley becomes occupied by an extensive and varied series of drifts including much brickearth (p. 119). On the north-east side of the valley the drift is distinctly a chalk rubble, variably flinty, which is banked high against the Chalk slopes. On the broader south-west slopes and in the valley bottom where this is not occupied by the brickearth the hillwash is a variable heavy loam, with much gravel locally, which soon merges, however, into the chalk rubble of the tributary valleys. The tendency of the drift to cling to the southern side of a valley is especially notable south of Darland and north-west of Luton. A gravel pit about a quarter of a mile north-west of Luton Church formerly exposed, above the Chalk, about 12 ft of interbedded loam with subangular flints and lenticular gravel.

South of Darland, on the west side of the road to Hempstead, rough flinty drift clearly derived from the Clay-with-flints contains a matrix of interstratified brickearth and dark manganese-stained flinty clay, the latter nearly always forming the base. The deposit is crudely bedded corresponding with the slope of the hill. In addition to large nodular flints and small chips there are occasional green-coated flints from the base of the Thanet Beds, Tertiary pebbles and lumps of sarsen-stone. A thickness of 5 ft to 10 ft lies irregularly on the Chalk. About 250 yd west-north-west of the cross-roads at Hale, brickearth and loam, flinty in the upper part, and banked against the hillside were seen to 12 ft. The following section was seen about a quarter of a mile south-west of Luton Church about 200 yd south-west of Stonecross Farm:

	Ft
Brickearth and loam with subsidiary gravel and with a clayey base	5 to 10
Silicified chalk breccia and rubble (*see* p. 134)	2

This rested on an irregular surface of flint-bearing chalk. The site has yielded flint implements referred to late Acheulian or early Mousterian age (Turner 1928, p. 299).

In the system of valleys south-east of Bredhurst the drift consists mainly of chalky loam and rubble with a high proportion of flints. Downwash from the Clay-with-flints mantles the higher slopes, especially on the south and west sides of the valleys; it covers the shallow valley-bottom south of Westfield Sole and occurs west of Lower Cox Street and west of Scragged Oak. Near Queen Down Warren the deposits become more variable. On the steep north side of this valley, chalk rubble with flints extends from about half a mile east-south-east of Kemsley Street to beyond Queen Down Warren. In a chalk-pit 700 yd south-east of Oak Barn 4 ft to 8 ft of variably earthy chalk and flint rubble were seen to pass down into weathered and disintegrated chalk. The floor of the valley is occupied by a coarse gravelly loam with pellets of chalk, gradually passing into a Head Gravel of the younger group (p. 108) at Hartlip. A borehole at the Matts Hill Pumping Station (272/106) proved 8 ft of drift, the middle portion being gravel.

South-east of Hartlip 6 ft of hillwash were seen in the lane-cutting 250 yd west of Sweepstakes Farm, and over 8 ft of brown loam with flints, chalk pellets and glauconitic material derived from the Thanet Beds, in the lane leading from Hartlip Church to Lower Hartlip.

Bordering the Clay-with-flints west and south of Rainham Mark up to 6 ft or more of flinty loam and clay downwash irregularly overlie the Chalk on a gentle north-easterly slope. A temporary section just over half a mile south-east of Rainham Mark showed 3 ft of glauconitic loam with flints, ironstone, sarsens and chalk pellets, without reaching the Chalk. A chalk-pit a quarter of a mile north-west of Cozenton showed 6 ft to 8 ft of flinty loam and brickearth, with glauconite derived from the Thanet Beds, the drift also occurring in solution pipes in the Chalk. S.C.A.H.

On the lower part of the Chalk dip-slope west and north-west of Strood large spreads of head occupy the valley slopes and bottoms. On the slopes these deposits are largely composed of material from the Thanet Beds and other lower Tertiaries and from the remanié patches of gravelly head that occur around Higham Upshire and on Broom Hill. Priest and Epps (1935, p. 64) noted chalky Coombe Rock overlain by loamy hillwash in sections near Higham Station; also a pebbly hillwash in the Higham Upshire district. In the valley bottoms the head, composed of similar materials but with a considerable admixture of chalk in the form of rubble, may be 10 ft or more thick. In the higher parts of the small valley, 1000 yd north-west of Temple Farm, Strood, the Head Brickearth (p. 117) is overlain by 3 ft of hillwash, consisting of dark grey cloddy loam with small pellets of chalk and some small flints, apparently a colluvial accumulation derived from soil of the surrounding chalk country.

The London Clay forms a ridge of country up to 200 ft O.D. from just east of Higham to Allhallows. The western end of this outcrop and the north-westerly slopes of the ridge, facing the Thames estuary, are free from head though there is a sparse scattering of stones in the clayey soil. The south-easterly slopes, facing the Medway estuary as well as the London Clay outcrops around Binney Farm, east of Allhallows and on the Isle of Grain, are, on the other hand, extensively covered with hillwash. The deposit, derived from London Clay and river gravel, gives rise to a buff, crumbly loam with varying quantities of stones, in places rather sandy and in others clayey but generally supporting an easily-worked soil. The thickness on the slopes is normally 2 ft or 3 ft but accumulations in valley bottoms or depressions in the slopes may be much thicker.

Hillwash occurs on the eastern slopes of the hill at Great Wood, 2 miles west-south-west of Strood, where gravelly material, from the capping of supposedly Pliocene deposit (p. 94), slumps across the outcrop of Thanet Beds to rest on the Clay-with-flints spreads around Ranscombe and Head Barn Wood; the other slopes of the hill appear to be free from wash. H.G.D.

A deposit of hillwash derived mainly from Clay-with-flints covers the Chalk west of Hartlip. Near the Clay-with-flints this is very flinty but traced northward there is a progressive decrease in the amount of flints and the deposit gradually assumes the character of brickearth. A section was seen in the south-west face of a large chalk-pit 700 yd north of Rainham Station, where 3 ft of dark brown sandy clay with flints rest on 5 ft of biscuit-coloured clay with chalk fragments and flints, in turn resting on Chalk. Much of the Chalk outcrop north of Stockbury is covered by a wash of sand from the Thanet Beds with an admixture of debris from the Clay-with-flints.

Rather gravelly head occurs to the north of, and is derived from, the gravel deposit on the hill about three-quarters of a mile south of Upchurch, where the presence of shallow pits suggests that it was at one time used as a source of gravel. North of the railway half a mile west of Bobbing, a thin spread of sand with flints, clayey in places, surrounds two thin patches of gravel.

In the Stockbury Valley west and south-west of Borden Hill, road-cuttings exposed up to 8 ft of red and red-brown loam with flints, pebbles and pieces of chalk. From Borden Hill sandy and flinty loam, on an average about 3 ft thick, extends in two tongues east and west of Oak Street. Sandy head from the Thanet Beds covers the Chalk on the east side of the Stockbury Valley in the neighbourhood of Chestnut Street, and dry valleys around Borden Lane and Tunstall and eastward contain a sandy loam with flints, sometimes with fragments of chalk. J.A.R.

PLEISTOCENE MOLLUSCA FROM THE CHATHAM DISTRICT

The following records are taken from notes by A. S. Kennard:

CUXTON AND HALLING DISTRICT

Five species were found in the bed containing the Halling Skeleton (p. 115): *Pomatias elegans* (Müller), *Trochulus hispidus* (Linné), *Helix nemoralis* Linné, *Retinella nitidula* (Draparnaud) and *Vortex lapicida* (Linné). The first three also occurred in the stream channel above the bed and *Gonyodiscus rotundatus* (Müller) and *Arion sp.* were also recorded [see also Kerney 1963, pp. 218–9].

Section one-third of a mile north-east of Cuxton Station, close to the river and nearly at high tide level. Shells were not common, and were very scattered. They comprised:

Pupilla muscorum (Linné)	Abundant
Vallonia excentrica Sterki	4
Vallonia costata (Müller)	3
Zua lubrica (Müller)	2
Arion sp.	Common
Limax sp.	1
Trochulus hispidus (Linné)	9
Helix nemoralis Linné	1
Cecilioides acicula (Müller)	3

Mollusca from the four following localities are listed together:

(1) Trechmann's or Whorns Place pit (*see* p. 127).
(2) Batchelor's pit (*see* p. 127).
(3) Hilton's pit (*see* p. 126).
(4) Lee's pit (*see* p. 126).

More collecting was done at (1) and (2) than at (3) and (4).

	Number of specimens of each species*			
	(1)	(2)	(3)	(4)
Pomatias elegans (Müll.)	4	1	4	–
Carychium tridentatum (Risso)	–	–	3	–
Abida secale (Drap.)	8	abn	5	6
Pupilla muscorum (Linné)	abn	abn	–	com.
Vallonia excentrica Sterki	6	10	–	–
Vallonia costata (Müll.)	com.	abn	3	4
Zua lubrica (Müll.)	abn	abn	–	com.
Punctum pygmaeum (Drap.)	–	com.	1	1
Gonyodiscus rotundatus (Müll.)	7	1	1	–
Arion sp.	abn	abn	com.	com.
Petasina fulva (Müll.)	2	8	–	4
Oxychilus cellarius (Müll.)	2	–	–	–
Retinella pura (Alder)	2	–	–	–
Retinella radiatula (Alder)	2	com.	2	4
Vitrea crystallina (Müll.)	–	–	1	–
Limax sp.	2	6	–	–
Vitrina pellucida (Müll.)	4	5	1	6
Helicopsis striata (Müll.)	abn	abn	2	com.
Trochulus striolatus (C. Pfeiffer)	3	–	–	–
Trochulus hispidus (Linné)	com.	abn	com.	6
Planatella itala (Linné)	9	com.	4	5
Arianta arbustorum (Linné)	8	abn	7	3
Helix nemoralis Linné	–	–	1	–
Helix hortensis (Müll.)	2	–	–	–
Cecilioides acicula (Müll.)	4	6	–	com.
Succinea pfeifferi (Rossmassler)	1	–	–	–
Number of species	22	17	15	14

*abn = over 50 examples.
com. = 10 to 50 examples.

The occurrence of the marsh species *Succinea pfeifferi* is probably due to a bird.

From the evidence of the above, Kennard concluded that the climate existing at the time the deposits containing these shells were formed was similar to that of today.

SITTINGBOURNE DISTRICT

From the upper layer of a pit seven-eighths of a mile south-east of Sittingbourne Station, Mr. H. C. Berdinner obtained *Pupilla muscorum* and *Succinea oblonga* (Draparnaud), the latter being common.

From Murston Road, Mr. J. P. T. Burchell obtained:

Bythinia tentaculata Linné
Valvata piscinalis (Müller)
Lymnaea peregra (Müller)
Lymnaea truncatula (Müller)
Planorbis laevis Alder
Planorbis leucostoma Millet
Pupilla muscorum (Linné)
Arion sp.
Pisidium amnicum (Müller)
Pisidium henslowanum (Sheppard)
Pisidium subtruncatum Malm
Pisidium vincentianum B. B. Woodward
Sphaerium corneum (Linné)

P. vincentianum is extinct in the British Isles, and the only other record is from the early Holocene of Killough, County Down (Oldham 1935, p. 167). This species was originally described from the Pleistocene (Campinien) at Soignies, Belgium (B. B. Woodward 1921).

UPCHURCH AND TEYNHAM DISTRICTS

Prestwich (1892, p. 307) obtained *Pupilla muscorum* and *Succinea oblonga* from lenticular layers of grey laminated clay at Upchurch. *Pisidium supinum* A. Schmidt has been obtained from a pit one mile west of Teynham railway station.

Late-glacial and Post-glacial deposits in the Medway Valley have since been separated by Kerney (1963, pp. 210–9) following detailed studies of their mollusca. Burchell (1965) has also subdivided deposits at Halling by their molluscan content.

CHALK BRECCIA

At scattered localities on the Chalk slopes, both of valleys and escarpment, and usually not far distant from drift lying at a higher level, are found tabular masses of a hard chalk breccia generally containing flints, in a calcite mudstone matrix which may be partly silicified. A similar deposit has been noted in the adjacent Sevenoaks area, and elsewhere on the Chalk Downs.

Tabular masses of chalk-flint breccia were seen about 500 yd south-east of the Robin Hood and Little John Inn above Burham, set amongst clayey wash and chalky rubble (*see* Hood 1884, p. 62). A specimen (E. 21729) examined petrographically by Dr. K. C. Dunham is described as being a porous breccia of angular fragments of white hard chalk (calcite mudstone) in a matrix of buff-coloured calcite mudstone. The fragments and the matrix are scarcely distinguishable from one another under the microscope; both rocks contain abundant chalk 'spheres', remains of shells, foraminifera and echinoid spines in a matrix of cryptocrystalline calcite mud. Small streaks of brown collophanite are present, and there are scattered single crystals of calcite probably derived from crinoid ossicles. Similar rock was seen half a mile south by west of Nashenden Farm; in the road bank, on the west side, 250 yd south of Snodhurst; a quarter of a mile west of the church at Hempstead (apparently a vertical seam in the Chalk, and without flint); and in the old gravel and brickearth workings a quarter of a mile south-south-west of Luton Church, near Stonecross Farm (*see* p. 130), where the rock immediately overlies normal chalk and is covered by some 10 ft of drift; the breccia is silicified and very flinty but cementation is not always complete. The origin of this cemented rubbly drift may be related to waters percolating from drifts higher up. The material bears some resemblance to beds of 'chalk-rock' type in the Chalk formation. S.C.A.H.

REFERENCES

ANDREWS, C. W. 1915. Discovery of a Skeleton of *Elephas antiquus* at Upnor, Kent. *Journ. Conchology*, vol. xxv, pp. 353–8.

—— and C. FORSTER COOPER. 1928. *On a Specimen of Elephas antiquus from Upnor.* Brit. Mus. (Nat. Hist.).

BENNETT, F. J. 1904. Excursion to Cuxton. *Proc. Geol. Assoc.*, vol. xviii, p. 463.

BURCHELL, J. P. T. 1965. An Interstadial Horizon of the Last Glaciation at Halling, Kent. *Journ. Conchology*, vol. xxv, pp. 353–8.

Cook, W. H. 1914. On the discovery of a Human Skeleton in a Brick Earth Deposit in the Valley of the River Medway at Halling, Kent. *Journ. Roy. Anthrop. Inst.*, vol. xliv, p. 212.

—— 1923. Excursion to Addington, Coldrum and Halling. *Trans. S.E. Union of Scientific Societies*, vol. xxviii, p. lxxiii.

—— and J. R. Killick. 1924. On the discovery of a flint-working site of Palaeolithic date in the Medway Valley at Rochester, Kent, with notes on the drift-stages of the Medway. *Proc. Prehist. Soc. E. Anglia*, vol. iv, p. 150.

Dibley, G. E. 1900. Excursion to Cuxton and Burham. *Proc. Geol. Assoc.*, vol. xvi, p. 249.

—— 1918. Additional notes on the Chalk of the Medway Valley [and other districts]. *Proc. Geol. Assoc.*, vol. xxi, p. 68.

—— 1922. Excursion to Blue Bell Hill, Rochester. *Proc. Geol. Assoc.*, vol. xxxxiii, p. 75.

Dines, H. G. 1927. The Flint Industries of Bapchild. *Proc. Prehist. Soc. E. Anglia*, vol. vi, pt. 1, p. 12.

—— and F. H. Edmunds. 1933. Geology of the Country around Reigate and Dorking. *Mem. Geol. Surv.*

——, S. E. Hollingworth, Wilfrid Edwards, S. Buchan and F. B. A. Welch. 1940. The Mapping of Head Deposits. *Geol. Mag.*, vol. lxxviii, No. 3, p. 198.

Foster, C. le Neve and W. Topley. 1865. On the Superficial Deposits of the Medway, with remarks on the Denudation of the Weald. *Quart. Journ. Geol. Soc.*, vol. xxi, p. 443.

Godwin-Austen, R. A. 1857. On the Newer Tertiary Deposits of the Sussex Coast. *Quart. Journ. Geol. Soc.*, vol. xiii, p. 40.

Goodchild, J. G. 1886. Notes on some superficial deposits of North Kent. *Proc. Geol. Assos.*, vol. ix, p. 151.

Hood, A. W. 1884. The Chalk of the Medway Valley. *Rochester Naturalist*, vol. i, No. 4, p. 57.

Hutchings, G. E. 1924. Report of the Geology Section of the Rochester and District Naturalists' Club. *Rochester Naturalist*, No. 130, vol. vi, p. 63.

—— 1925. The River Deposits of the Lower Medway Basin. *Proc. Geol. Assoc.*, vol. xxxvi, p. 419.

Johnson, J. P. 1902. Eolithic Implements from the Plateau Gravel around Walderslade, Kent. *Essex Naturalist*, vol. xii, p. 207.

Kennard, A. S. 1944. The Crayford Brickearths. *Proc. Geol. Assoc.*, vol. lv, pp. 121–69.

Kerney, M. P. 1963. Late-glacial Deposits on the Chalk of South-East England. *Phil. Trans. Roy. Soc.*, (B) vol. 246, pp. 203–54.

Newton, E. T. 1904. Report of Palaeontological Work. *Sum. Prog. Geol. Surv.*, for 1903, p. 60.

Oldham, C. 1935. *Pisidium vincentianum* in a Kentish Pleistocene Deposit. *Journ. Conchology*, vol. xx, p. 167.

Prestwich, Sir J. 1865. On the Loess of the Valleys of the South of England, and of the Somme and the Seine. *Phil. Trans. Roy. Soc.*, vol. 154. p. 247.

—— 1892. On the Raised Beaches and 'Head' or Rubble Drift of the South of England. *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 263.

Priest, S. and F. J. Epps. 1935. Field Meeting at Higham and Shorne, Kent. *Proc. Geol. Assoc.*, vol. xlvi, p. 61.

Salter, A. E. 1905. On the Superficial Deposits of Central, and parts of Southern, England. *Proc. Geol. Assoc.*, vol. xix, p. 1.

Sherlock, R. L. and A. H. Noble. 1912. The Glacial Origin of the Clay-with-flints of Buckinghamshire. *Quart. Journ. Geol. Soc.*, vol. lxviii, p. 199.

Topley, W. 1875. The Geology of the Weald. *Mem. Geol. Surv.*

Trimmer, J. 1853. On the Origin of the Soils which cover the Chalk of Kent. Part 3. *Quart. Journ. Geol. Soc.*, vol. ix, p. 286.

Turner, J. 1928. On an Early Palaeolithic Workshop site at Stonecross, Luton, Chatham. *Proc. Prehist. Soc. E. Anglia* for 1927, vol. v, p. 299.

Whitaker, W. 1872. Geology of the London Basin. *Mem. Geol. Surv.*

White, H. J. O. 1928. Geology of the Country near Ramsgate and Dover. *Mem. Geol. Surv.*

Woodward, B. B. 1921. *Catalogue of Species of* Pisidium. Brit. Mus. (Nat. Hist.).

Chapter X

PLEISTOCENE AND RECENT (CONTINUED)

RIVER DEPOSITS

PART of the Thames Estuary borders the northern part of the Chatham district, and the River Medway traverses the outcrops of the Cretaceous and Tertiary strata from north of Snodland to its junction with the River Thames at Sheerness; between the Isle of Sheppey and the mainland runs the Swale. Large alluvial tracts fringe the Thames and Medway Estuaries, and also the Swale. In the whole of the area east of the Medway valley no permanent stream crosses the outcrops of the solid rocks, but across the wide alluvial tracts water finds its way to the sea by way of numerous creeks which join either the Swale or the Medway. Some of these are fed by overflow springs rising from the Tertiary formations at or close to the margin of the alluvium as, for example, the Lower Halstow Creek, the stream of which rises near Newington Church; Milton Creek, rising near Sittingbourne, and the Tonge stream rising near Bapchild.

Gravels of river origin are, therefore, practically confined to the valleys of the Thames and Medway, though a few occurrences, presumably of river origin, have been proved below the alluvium in more easterly parts. There are no remaining traces of gravel to support the view, generally held, that the Swale has been formed by river action, for the gravels capping the Bagshot outliers at 200 ft O.D. on the north side of the Isle of Sheppey are deposits of head.

The chief area of river gravels is that of the peninsula of Allhallows and the Isle of Grain, between the Thames and the Medway. Here, the Tertiary strata form a ridge of ground that rises above the 200-ft contour in Great Chattenden Wood, extending for a mile eastwards from Chattenden Farm, and again at Lodge Hill. The northern slopes of the ridge, on the Thames side, are steep and landslips in the London Clay are extensive (Plate VIA). To the north-east and east of High Halstow, Lodge Hill and Chattenden Farm, however, the surface slopes gently towards the Medway and the main spreads of gravel occur mantling these slopes from the highest point (240 ft at Lodge Hill) down to about 50 ft. The higher spreads seldom exceed 5 ft or 6 ft in thickness, and though they have probably been smeared down the slopes by solifluction, they appear to have been laid down as a series of terraces of river origin, as indicated by even bedding of intercalated sand seams, their fairly uniformly ochreous character and high content of cherts from the Lower Greensand.

The following terraces have been recognized:

4th Terrace	150 ft to 210 ft O.D. or higher
3rd Terrace	90 ft to 150 ft O.D.
2nd Terrace	40 ft to 100 ft O.D.
Low Terrace	up to 50 ft O.D.
Buried Channel	down to −99 ft O.D.

The very small and isolated occurrence at 240 ft on Lodge Hill has been included with the 4th Terrace: it may, however, represent a yet higher stage.

The 3rd Terrace may be equated with the 'Upper Terrace' of Cook and Killick (1924, p. 138) and the '100-ft Terrace' of G. E. Hutchings (1925, p. 423); the 2nd Terrace with the 'Middle Terrace' and '50-ft Terrace' respectively of these authors, the Low Terrace with their 'Low Terrace' and '25-ftTerrace'.

Mr. Hutchings groups certain deposits higher than a recognizable 100-ft Terrace as 'High Level Deposits', which contain the present 4th Terrace. Correlation of the various members of this group with the Boyn Hill (High or 100-ft) Terrace, Taplow (Middle or 50-ft) Terrace and Flood Plain Terrace of the Thames is indefinite. It has been shown by C. E. N. Bromehead (Dewey and Bromehead 1924, p. 98), that the level of the Taplow Terrace drops to flood plain level or below east of Dartford. Similarly, the Second Terrace of the Stour falls below flood plain level at Preston, north-east of Canterbury. In the Chatham area, gravels taken as 2nd Terrace occur extensively in the Medway valley at levels above 40 ft O.D. The 3rd and 4th terraces may represent respectively the Boyn Hill Terrace of the Thames and the chert-bearing river gravels capping the Rayleigh Hills in Essex at 250 ft O.D. (*see* Wooldridge 1923, p. 320; 1928, p. 11), but the latter are probably dissected sheets of ancient Head Gravels similar to those in north-east Kent. The 4th Terrace gravels north of the Medway are not clearly separable from Head.

It is clear that the terraced gravels are all later than the Clay-with-flints; there is no evidence for any Head or Head Brickearth deposited during the period of the 4th, 3rd and 2nd terraces and all the post Clay-with-flints examples of these deposits were formed subsequently to the 2nd Terrace. Flint artefacts have been discovered at a few localities, notably hand axes of St. Acheul type at Frindsbury and more recent flakes (*see* p. 115) at Halling (Cook and Killick 1924, pp. 144 and 152) while Epipalaeolithic, Iron Age and Romano-British remains have been found at High Halstow (Burchell 1928, p. 288).

H.G.D., S.C.A.H.

DETAILS

4TH TERRACE GRAVELS. These occur only around High Halstow and near Chattenden Farm, west-north-west of Hoo. At 1000 yd north of High Halstow Church two small patches, little more than remnants of a wider spread that has been largely removed by land slipping, cap Northward Hill at a height of 209 ft O.D. At High Halstow village a spread sloping eastwards from the 200-ft level at the church contains ochreous sand and gravel with flints and cherts, seen in pond-side exposures to a depth of 4 ft. It is apparently separated from a slightly lower patch to the east, the surface of which also slopes eastwards to a hill below 150 ft, marked by large lumps of iron-cemented gravel or pan turned up by the plough. In the Clinch Street Farm and Newlands spread the highest point is about 190 ft and the surface falls gently eastward to 150 ft at Newlands. A very small patch at 209 ft caps high ground 1000 yd east of Chattenden Farm, where 2 ft of ochreous sand and gravel with brown flints and cherts, some large, were exposed. The soil on the London Clay hill top in Round Top Wood and in Great Chattenden Wood contains a scattering of stones. About 1000 yd north of Chattenden Farm a small isolated patch of gravel, 300 yd long by 100 yd broad, caps the crest of a ridge known as Lodge Hill at 240 ft O.D. The northern margin abuts against the top of a steep landslip feature in London Clay, scars in the slip showing pockets of tumbled gravel. This spread is over 30 ft higher than the nearest occurrences of gravel of the 4th Terrace, respectively east of Chattenden Farm, and at High Halstow. In view of the general easterly slope of about 30 ft in half a mile of other 4th Terrace gravel spreads, this is also regarded as a remnant of the 4th Terrace.

Various gravelly patches classed as head between Shorne and Higham Upshire, on Broom Hill and along the south side of Watling Street between there and Park Pale, may represent remnants of gravel of the 4th Terrace; all are above the 200-ft contour and those on Broom Hill and nearby are up to 260 ft O.D. They contain ochreous and white flints, Tertiary pebbles and Lower Greensand chert.

3RD TERRACE GRAVELS. These are extensively spread over the area between High Halstow and Allhallows and, like those of the adjacent 4th Terrace, these spreads show a tendency to extend down the hill slopes. The largest spread of this terrace, around Dagnam Farm, Allhallows, slopes gently from a central surface level of about 135 ft O.D. to about the 100-ft contour southwards, eastwards and northwards. Old pits are about 6 ft deep. The deposit consists of more or less evenly bedded sand and gravel, the uppermost 3 ft or so in most exposures being contorted. About a mile west of Stoke, old pits in a spread with a fairly level surface at 120 ft O.D. showed 5 ft of ochreous gravel and the development of sporadic iron pan.

Small patches lying at just over 125 ft O.D., south-east of Cooling, though in the Thames valley and cut off from the Medway by the 200-ft ridge of High Halstow, contain, in addition to ochreous flints, some of which show frost pitting, and Tertiary pebbles, much chert and other material derived from the Lower Greensand formation within the Weald, amongst which may be recognized specimens of green chert or Ightham Stone and quartzose sandstone resembling Oldbury Stone.

Two gravelly spreads north of Frindsbury may be of river origin; 5 ft of gravel on Thanet Beds were seen in a road bank a third of a mile south-west of Wainscot. About 200 yd east of Frindsbury Church, a terrace rests on a bench cut in the Chalk that here forms the valley side of the Medway near its confluence with the stream from Islingham Farm. A considerable part of the spread has been cut away in working the chalk quarry near the railway tunnel entrance. A description of the section seen about 1923 by W. H. Cook and J. R. Killick (1924, p. 133) shows that the bench at about 80 ft O.D., is horizontal but terminates on the west or landward side at a cliff-like rise of the Chalk surface to about 100 ft. Beds of sand, gravel and brickearth constitute the 3rd Terrace, but it is clear from their account that the river deposit is disturbed in the upper part and is overlain by deposits of head, in which the palaeolithic implements found by them occurred in a position somewhat higher than, and westwards of, the upper landward limit of the river terrace. The implements include both core hand axes and flake tools, and are assigned to the St. Acheul II and Le Moustier stages. The whole valley slope is covered by a comparatively thin layer of red head-brickearth sweeping over the earlier head, the river gravels and the solid rocks, down almost to the level of the alluvium; boundaries are consequently much obscured. A small, isolated patch of 3rd Terrace gravel up to about 6 ft thick, capping Tower Hill, south-west of Upnor, appears to consist of densely packed stones, some of which, especially the cherts, are of comparatively large size, often a foot or so across. H.G.D.

At Gillingham, three small spreads of 3rd Terrace gravel, a little above the 100-ft contour, with a highest level of about 120 ft O.D., rest on Thanet Sand. The centre spread is cut into by the railway, the cutting showed 6 ft of ferruginous sandy gravel containing subangular flints, flint pebbles, and Lower Greensand chert. This gravel has, according to G. E. Hutchings (1925, p. 425), yielded large numbers of palaeolithic implements. S.B.

A patch of subangular flinty gravel, with chert and ironstone, occurs, up to about 150 ft O.D., half a mile north-east of Wouldham Church. Its boundaries are obscured by head. S.C.A.H.

2ND TERRACE GRAVELS. Represented in the Thames valley by only a few scattered patches, this terrace is fairly extensive in the Medway valley, between Allhallows and Hoo and eastwards to the Isle of Grain. There are smaller patches between Upnor and Frindsbury and the terrace can be traced upstream at Cuxton, between Borstal and Wouldham and on both sides of the river near Snodland.

In the Thames valley a spread 1½ miles north of Shorne lies above the 50-ft contour. A small area of gravelly soil around Cooling Church at about 40 ft O.D., not indicated on the 1-in geological map, may be a remnant of this terrace. A very small patch about a mile N.E. of St. Mary's Hoo, at the 50-ft level, has been excavated to a depth of 6 ft; the top half of the exposure shows contortions but below the gravel and sand are more or less evenly bedded. Slough Fort, half a mile north of Allhallows, is on a small spread at the confluence of the Thames and Medway; at the fort the gravel appears to be about 12 ft thick.

A large spread almost covers the Isle of Grain. It has a fairly flat surface between 40 ft and 45 ft O.D. in the central and northern parts but slopes southwards and westwards to about 25 ft; on all sides it is separated from the alluvium by a slope of London Clay. Old gravel pits north-west of Grain village are 8 ft deep in ferruginous sand and flinty gravel with chert, vein quartz and quartzite pebbles. At the Royal Naval Flying Station, south-east of the village, a well proved 6 ft of gravel on London Clay.

South-west of Allhallows, gravel 4 ft to 5 ft thick lies higher than the general level of the 2nd Terrace, i.e. between 60 ft O.D. and 75 ft O.D. On the north side of Lower Stoke, a small patch at about 45 ft O.D. has been worked in pits up to 8 ft deep. South of the village, the gravelly part of a brickearth occurrence (*see* p. 119) may represent part of the 2nd Terrace, but here the surface level is only a little above 30 ft O.D. The elongated spread on which the village of Stoke is situated is mainly above the 50-ft contour; old pits near the church and near Tudors are 3 ft to 4 ft deep.

North of Frindsbury, gravel west and south of Wainscot is 10 ft thick and lies just above the 50-ft contour. South of these gravels a spread of sandy brickearth, covering Low Terrace gravel, rises to about 2nd Terrace level at its southern end, where a section in the face of a chalk quarry south-east of Frindsbury Church shows this deposit to rest on a horizontal bench cut in the chalk slope of the valley side at about 45 ft O.D. The Chalk at the western or landward side rises almost vertically to 65 ft O.D. (*see* Cook and Killick 1924, Plate A, and Hutchings 1925, p. 425).

G. E. Hutchings gives the following section as seen about 1924:

	Ft	in
Sandy brickearth	10	0
Clean sand with grains up to 1 mm diameter		8
Ferruginous pea-gravel		6
Clean, coarse gravel with large subangular flints and pebbles	2	0
Grey and mottled clay	7	0
Thanet Beds	—	

The surface of the gravel underlying the brickearth is about 55 ft O.D. Hutchings makes it clear that the deposits vary considerably from place to place and advances the hypothesis that their position between higher ground to the north and south suggests that they represent part of an abandoned meander of the Medway.

A high proportion of Lower Greensand chert, often in comparatively large pieces, characterizes the gravel; one piece of Ightham Stone measuring 9 × 8 × 6 in was observed. A narrow spread borders the southern side of the Dockyard area at Chatham, in which a trial bore proved a thickness of 6½ ft of gravel beneath 3½ ft of made ground, and resting on Thanet Beds.

H.G.D.

Above Rochester the patches of 2nd Terrace gravel are small and scattered and are mostly but dissected relics, frequently obscured by head. At Cuxton, coarse gravelly sand and loam, chalky only at the top, and containing chert and ironstone, were seen to over 6 ft depth in the road-cutting 150 yd east-north-east of the church, and 3 ft to 6 ft of similar drift with brickearth on the north-west side of the adjacent railway-cutting. Kennard states that Acheulian implements have been found in this deposit.

East of Wouldham Marshes, of four small patches of ochreous sandy gravel surrounded by hillwash, the southerly patches reach the 100-ft contour and may be considered as relics of the highest part of the terrace, banked against the Chalk slope.

At Halling the old quarry-cutting west of the church exposed gravelly sand beneath the hillwash (*see* p. 126) indicating a covered patch of 2nd Terrace gravel, or pockety relics of it. The spread of gravel around Rookery Farm, Snodland, overlapped by hillwash, was noted by Topley (1875, p. 173) but the north-easterly extent (beneath the Head) is probably not as great as he implied. On the east side of the large Holborough Chalk Quarry, 150 yd west of the road, a section in a small area of 2nd Terrace gravel beneath head showed coarse sandy subangular gravel with Tertiary pebbles, chert and ironstone, in places clearly bedded but elsewhere irregularly intermingled with the head.

At Ham Hill (*see* p. 125) current-bedded gravelly sand and loam occurs in places beneath head as local small relics of 2nd Terrace gravel. The thickness may be up to 9 ft as shown by records of trial holes, and it is possible that some of the underlying sand recorded as Folkestone Beds may have been re-deposited, since the pit face exposed at one point a bed of subangular flints 2 ft down in apparently undisturbed sand.

Bedded well-worn sandy gravel, with chalk and Lower Greensand materials, to a thickness of 6 ft or more, was seen to rest on the Gault in old clay workings half a mile west of Eccles. S.C.A.H.

LOW TERRACE GRAVELS. Low Terrace gravels border the alluvial tracts and, passing beneath the alluvium, appear to merge with deposits of the Buried

Channel while landwards their surface level may rise locally to 50 ft O.D. or more.

In the Thames valley an extensive spread north of Shorne, with a general surface level of between 15 ft and 30 ft O.D., rises to 50 ft south of Queen's Farm. Between the road and the southern margin of the gravel at 1000 yd west-north-west of this farm, a large pit, in 1920, showed up to 20 ft of gravel with dark bands of iron or manganese staining near the base and layers of sand near the top. Large sarsens up to 6 ft in length were present, and in 1937 15 ft of gravel were exposed about the same distance north of the farm. In 1945 trial boreholes put down between these two pits proved ballast with subsidiary sandy and clayey beds to a maximum thickness of 34½ ft, resting on the Chalk, but Thanet Beds were apparently reached 15 ft to 17 ft down on the north side of the site. Of two wells at the nearby Uralite Works, one (272/74a) proved 16½ ft of drift, while the other (272/74b) passed through 18 ft of ballast on 3 ft of stony clay, resting on 6 in of peat. H.G.D., S.C.A.H.

Gravel excavations, 1¼ miles north of Shorne, carried to below the level of the alluvium, from a surface level of 25 ft O.D., showed, in 1937, the following section:

		Ft
Head	Chocolate-brown clay with starchy fracture on the higher parts of the gravel and passing on to London Clay which rises south-eastwards from beneath it	4
	Brown clay with rough lines of stones, chiefly black Tertiary pebbles but a fair proportion of ochreous and grey sub-angular flints and some chalk fragments	6
Low Terrace River Deposits	Yellow false-bedded sand	6
	Bedded sand and gravel, ochreous, with some large sandy claystone nodules (possibly from the Woolwich Beds) at various levels	12
	Below this had been encountered:	
	Loam	2–3
	Gravel resting on London Clay	2

The upper surface of the yellow sand layer was approximately level with that of the adjacent alluvium, the drift thus extending to over 20 ft below that level. On the opposite bank of the river, at East Tilbury, even-bedded sand and gravel 8 ft thick has a surface level of about 30 ft O.D. Dewey and Bromehead (1924, p. 105) class this last as Taplow Terrace.

At the foot of the steep, northern, London Clay slopes of the High Halstow ridge and bordering St. Mary's Marshes, the gravel may be 4 ft to 5 ft thick. The small thin spread, with surface level about 25 ft O.D., which caps the low hill of Binney Farm may belong either to the Thames or to the Medway.

In the Medway valley, Low Terrace gravel underlies the Hoo brickearths. It is not known whether the brickearth at North Street is so underlain, but gravels occur from Kingsnorth westward to beyond Hoo, occupying about half the width of the brickearth area on its riverward side. In the abandoned railway-cutting 600 yd south-east of Beluncle, the brickearth rests on London Clay, but a well about 200 yd south-east of the cutting and 300 yd south-west of Kingsnorth proved 10 ft of ballast, clay and sand on London Clay, below 8 ft of brickearth. Between Eshcol and Abbot's Court, gravel underlies brick-earth at depths from 2 ft to 8 ft and just west of the latter place there are 6 ft of brickearth on 8 ft to 10 ft of gravel. A section 800 yd south-east of Hoo Church, in 1938, was as follows:

	Ft	in
Red-buff clayey brickearth	3 to 4	0
Roughly false-bedded gravel	4	0
Buff loam with rootlet holes		4
Very dark brown compact, ferruginous gravel	1	0
Buff loam		2
Yellow sand		6
Compact, red-brown gravel with a rather loamy matrix, containing large battered flints, ochreous subangular flints, Tertiary pebbles and chert	seen to 7	0

At 500 yd south-west of the church the workings showed:

	Ft
Brickearth	4 to 5
Even-bedded sand with 1-in to ½-in pipe-clay seams with rootlet holes and streaks of stones in the lower part	4 to 5
Even-bedded sand and gravel with many large chalk flints with battered cortex	seen to 10

The sub-brickearth surface of the gravel in the area south of Hoo ranges from about 15 ft O.D. near the margin of the alluvium to about 40 ft near the village. On the western margin of the deposits, about 750 yd east of Hoo Lodge, the upper surface of a deposit of evenly bedded sand and loam underlying the brickearth rises to a little over 50 ft. The absence of river-transported stones suggests deposition in the slackwater of a sheltered part of a meander at the eastern end of the east–west ridge on which Hoo Lodge stands. A dip of 2° west by north may be due to foresetting. The deposit may possibly be contemporaneous with or represent the basal part of the brickearth. In 1937 a small excavation showed up to 15 ft of sand. At one horizon or bed were found a few sharp black, unpatinated flint flake artefacts, some retaining areas of white cortex, all with flat striking platforms and large bulbs of percussion and two showing careful retouch in the form of end-scrapers. A Clactonian culture is suggested. The relationship between the Low Terrace river gravel, the brickearth and the sand is interpreted as shown in Fig. 6.

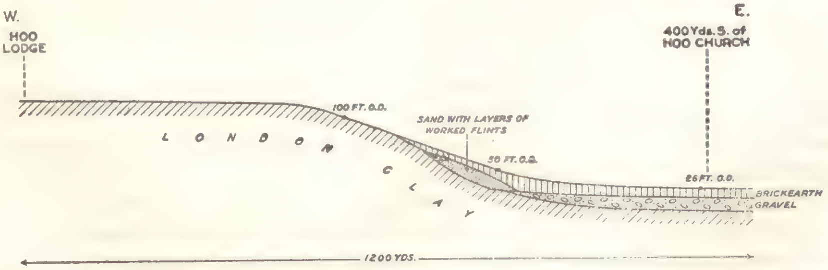


FIG. 6. *Diagram to show the presumed relationship between the Low Terrace River Gravels, Brickearth, and the Implement-bearing sandy deposits at Hoo*

The spread of Low Terrace gravel, lying at the foot of the steep river-cliff feature extending from Borstal to Rochester, is today being undercut by the eastward meander of the river; the surface level is about 18 ft O.D. The deposit, covered by hillwash (p. 128) and brickearth (p. 115) is only exposed near its southern end in the river-bank where the following section is to be seen:

		Ft
Head	Buff colluvial hillwash with chalk flints	3
	Red-brown brickearth with columnar structure, containing white flints, festooned into the underlying gravel	1 to 2
Low Terrace River Gravel	Pale buff, chalky, flint gravel with streaks of sand, disturbed in the upper part..	seen to 10

On the opposite side of the river gravel occurs beneath the riverward side of the spread of brickearth extending northward from Temple Farm, but its limits are not definitely known. It emerges from beneath the brickearth 500 yd south of the farm and crops out between the railway and the river at Wickham Cement Works, its surface level being about 20 ft O.D. About three-quarters of a mile north-east of Cuxton, a thickness of 16 ft of river gravel has been proved near the river beneath 26 ft of brickearth in a boring (272/28). The base of this gravel is at 12 ft below O.D. or about 27 ft below the surface of the alluvium. It may represent, therefore, the margin of buried channel deposits. H.G.D.

West of Borstal again, gravels of the Low Terrace underlie the head and brickearth. In the cutting leading to the river from the chalk-pit 300 yd north-west of Borstal Church, Hughes saw a bed of very hard gravel beneath 30 ft of overlying drift, below which was rough subangular gravel in coarse sand interstratified with beds of gritty sand. South-westwards the brickearth beneath the head thins laterally so that an area of gravel overlain only by thin chalky and gravelly head occurs bordering the alluvium; in the past this has been irregularly dug.

Apart from possible river gravel passed through in a borehole (272/12b) a quarter of a mile south-west of the cement works north of Halling (*see* p. 127), southwards the River deposits bordering the Medway are essentially brickearths, until a narrow strip of 1st Terrace gravel commences on the west bank at Halling and probably continues, entirely covered by head, as far as Holborough. The only recorded section is one 80 yd east-north-east of Halling Station (Cook and Killick 1924, p. 150) which showed about 4 ft of gravel, in four beds as below, underneath about 4 ft of head and 3 ft of bedded chalky brickearth:

4. Light brown sand with few stones.
3. Pebbly chalky gravel, with scattered angular flints, Lower Greensand debris and Eocene pebbles; overlain by a clay wash on the east side.
2. Light brown washed sand.
1. Angular flint gravel with Lower Greensand debris and Eocene pebbles.

From Holborough, where 5 ft of fine gravel with chalk beneath 20 ft of head were penetrated in a borehole at the cement works (272/128), the gravel probably continues southward beneath head. A well 100 yd north-east of Snodland railway station passed through 15 ft of head and 12½ ft of beds of Low Terrace deposits (loamy sand 11 ft, gravel 1½ ft), resting on the Gault. Bordering the river on the east side of the church, poorly exposed gravelly sand and loam with chalk, chert and ironstone may represent the gravel beneath head, but the deposits are not clearly distinguishable. It appears, however, from records of a number of boreholes at the Snodland Paper Mill (272/79) that the gravel merges here with that of the Buried Channel beneath the alluvium.

On the left bank of the Medway a strip of 1st Terrace gravel beneath head extends southward from Snodland. Old pits near Ham Hill exposed 4 ft to 8 ft with sand and, at one point, a 1-ft bed of ironstone and sandstone.

On the right bank of the Medway Low Terrace gravels are inferred to exist beneath head about a quarter of a mile south of Wouldham Hall; they also border the alluvium three-quarters of a mile west of Eccles. S.C.A.H.

BURIED CHANNELS. Records of wells and boreholes sunk on the alluvial tracts have disclosed a continuation of the Buried Channel of the Thames past Egypt Bay and St. Mary's Bay, and of a similar channel beneath the Medway marshes. The distribution of boreholes, and depths to below ordnance datum of the sub-drift surface of the solid strata are shown in Fig 7. These records give a general idea of the extent of the buried channels, but are insufficient to give a clear view of the form of their cross-sections. The available evidence suggests that gravels of the Low Terrace pass beneath the alluvium and merge with those of the Buried Channel.

The greatest depth at which river drift is proved is on the south-east side of the Isle of Grain where the London Clay was reached at 99 ft below O.D. overlain by 98 ft of alluvium and 6 ft of sand and gravel (272/218).

Two records between the Isle of Sheppey and the mainland showing depths of only 15 ft and 8 ft below O.D., suggest that the Swale alluvial channel is generally shallow, and may therefore be of quite recent origin. Neither of these records shows the presence of gravels.

In Buried Channel times the river appears to have cut through the Thanet Beds into the Chalk along a narrow east–west belt passing under the Chatham dockyard basins and eastwards along the south side of the present fairway. Gravel underlying the alluvial muds varies up to 25 ft in thickness but is frequently less than 10 ft.

Between Brompton and Upnor, the alluvium contracts to about half a mile in width and the Buried Channel, which must lie within this width, is probably much narrower than in the estuary.

North of Halling 15 ft of gravel floor the Buried Channel, and at Snodland, boreholes for the paper mill (272/79d–f) show 8 ft of gravel beneath about 22 ft of alluvium, while a further borehole there shows 32 ft of gravel beneath 6 ft of made ground; the bottom 9 ft is a sandy gravel (272/79c). Gravel reaches nearly to the surface at Snodland (272/79a–c), bordering the Low Terrace into which it seems to merge, and appears near the surface, 500 yd east of Snodland Church in the Medway channel, to form the 'Snodland Rocks'—a bar of iron-cemented conglomerate, with large and small flints and pebbly material (including chert, ironstone and ragstone from the Lower Greensand) visible at low tide. These appear to have been mistaken previously for 'firestone' of the Upper Greensand (Bensted 1862, p. 297; Topley quoting Drew 1875, p. 153). It may be that Topley misquoted Drew, since Whitaker (1872, p. 29) refers to a river section recorded by Drew a quarter of a mile north of Burham Church.

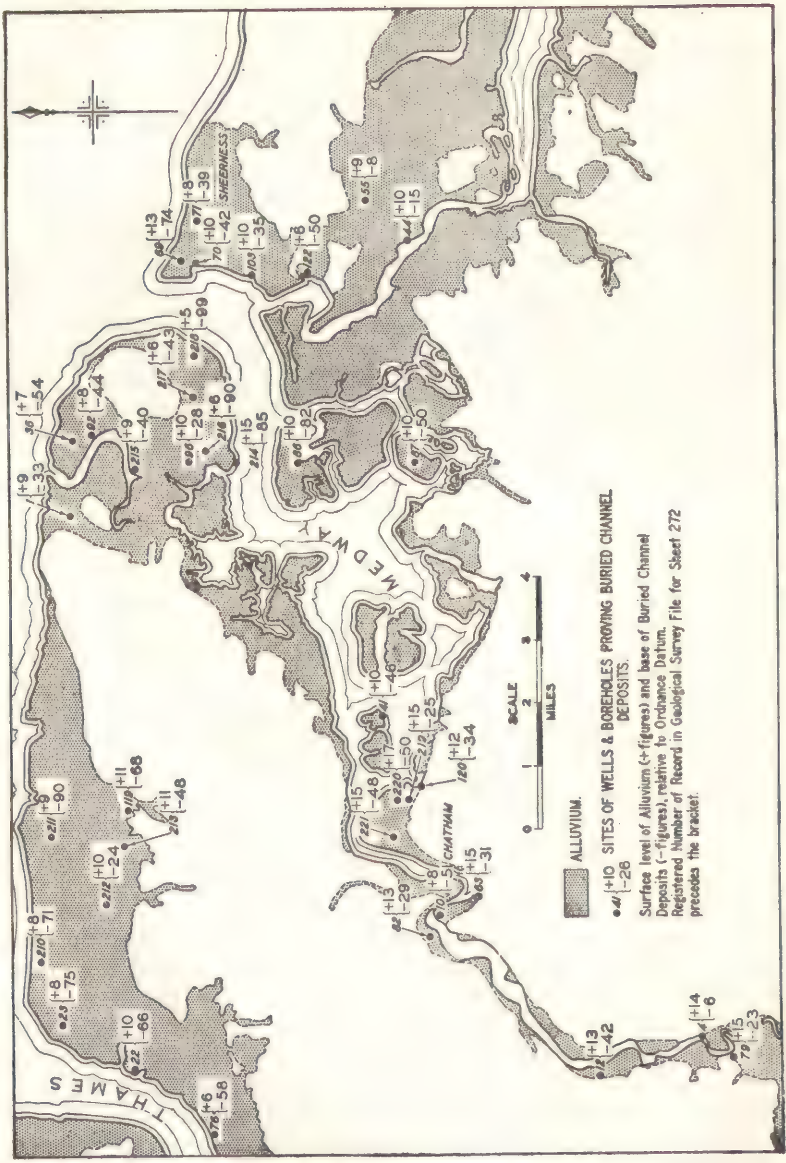

THAMES
MEDWAY
SHEERNESS
CHATHAM
SCALE
0 1 2 3 4
MILES
ALLUVIUM.
SITES OF WELLS & BOREHOLES PROVING BURIED CHANNEL DEPOSITS.
Surface level of Alluvium (+figures) and base of Buried Channel Deposits (−figures), relative to Ordnance Datum.
Registered Number of Record in Geological Survey File for Sheet 272 precedes the bracket.

FIG. 7. *Map showing sites of boreholes proving depths to the floors of the buried channels of the Rivers Thames and Medway within the Chatham District*

In the Thames valley the greatest depth of drift proved is in Halstow Marshes where a trial-bore passed through 99 ft of alluvium with sand and gravel and into Woolwich Beds at 90 ft below O.D.

The drift as recorded in most of the well and trial-bore records is sufficiently differentiated to show that the amount of river gravel covering the floor of the Buried Channel is very variable. The deepest drift record, south-east of the Isle of Grain, showed 6 ft of sand and gravel at the base, while in a borehole at Burntwick Island (212/86), 15 ft of gravel underlie 77 ft of sandy mud, etc., and at Milfordhope Marsh (272/87) 10 ft of gravel occur beneath 50 ft of river mud. Other boreholes show gravel to be absent.

The greatest thickness of Buried Channel gravels proved is 37 ft at Cliffe Fort (272/22) and again at Rose Court Farm, Isle of Grain (272/36). The gravel is sandy in both places. Beneath Halstow Marshes, 34½ ft of partly silty sand and gravel were proved while beneath Allhallows Marshes (272/1) the lower 31 ft of drift consist of 20 ft of yellow sand on 11 ft of gravel. In the Cliffe area as a whole, thicknesses of gravelly drift up to 35 ft are recorded, but at Chatham Dockyard the maximum known is 25 ft. At Snodland 32 ft of gravel in one boring (272/79c) at the paper mill are recorded, where Low Terrace gravel merges with that of the Buried Channel (*see* p. 144).

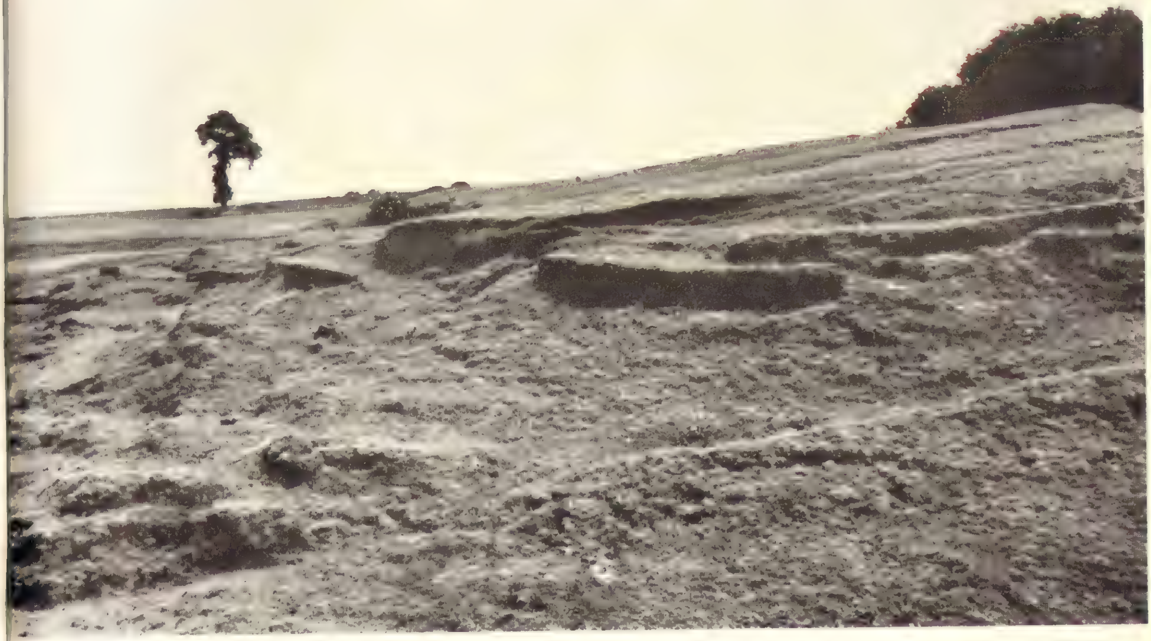
H.G.D., S.C.A.H.

ALLUVIUM

Extensive areas of alluvium are present in the Medway estuary, along the Swale channel and on the south side of the Thames estuary (*see* Plate VB). Along the Medway valley, however, between Rochester and Snodland, the alluvium is only a little over half a mile wide, but it broadens out again over the Gault outcrop south of Snodland.

Alluvial deposits in the main consist of blue-grey or brown-grey mud, usually with a high organic content, occasionally with streaks or beds of silt or loamy sand and here and there peat layers. Occasional gravelly bands and shell beds are also present. Peat, encountered in bores and excavations, has not been traced over wide areas and, as far as is known, occurs only as lenses of sporadic distribution. The thickness of peat beds seldom exceeds 2 ft, but 5 ft are recorded in the Thames estuary on Cooling Marshes (272/119), 6½ ft in a trial-bore three-quarters of a mile north-west of Cooling and 8 ft in one of the series of trial boreholes made around the Chatham Dockyard site; thicknesses of mud and silt recorded in the series are commonly between 30 ft and 40 ft; thicknesses around 50 ft are common in the Thames and Medway estuaries generally, and the greatest thickness proved is 98 ft, on the south-east side of the Isle of Grain; the mud and silt resting on a gravel bottom. A borehole at Cooling Marshes (272/119) only 250 yd from the landward edge of the alluvial tract, proved 79 ft of mud and silt, resting directly on the solid. At Cliffe Marshes (272/23) and Cliffe Fort (272/22) mud and silt beds are 48 ft and 39 ft thick respectively, in each case resting on gravel. In the Medway estuary, bores at Sheerness Dockyard (272/69a) and Burntwick Island (272/86) prove 81½ ft and 77 ft respectively, again resting on gravel. In the area of the Royal Dockyard at Chatham, trial bores show between 30 ft and 50 ft, generally with gravel below but occasionally resting on solid rocks.

H.G.D., S.C.A.H., S.B.

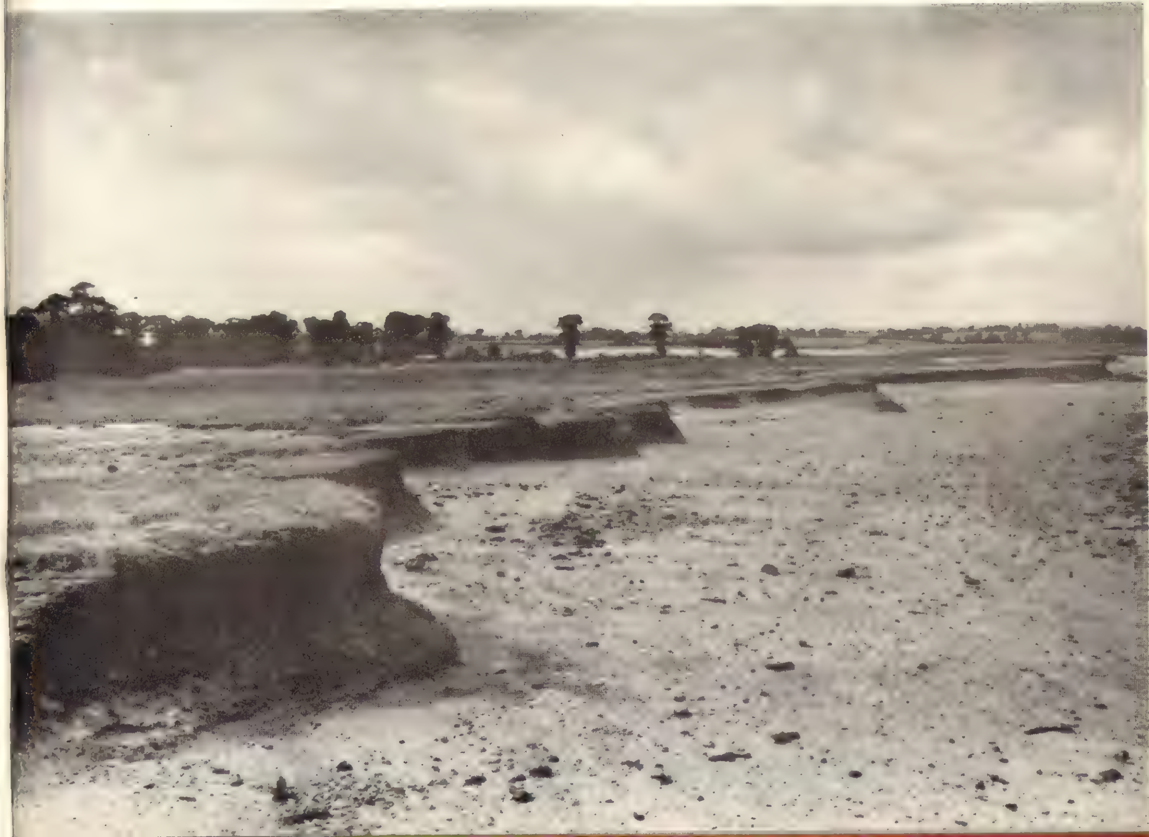


(A 7847)

A. Landslip in London Clay, High Halstow

B. Alluvial Flat, bordering the Thames Estuary, Allhallows

(A 7837)



REFERENCES

BENSTED, W. H. 1862. Notes on the Geology of Maidstone. *The Geologist*, vol. v, p. 294.

BURCHELL, J. P. T. 1928. Final Account of Excavations carried out at Lower Halstow, Kent. *Proc. Prehist. Soc. E. Anglia*, vol. v, Pt. iii, p. 288.

COOK, W. H. and J. R. KILLICK. 1924. On the Discovery of a Flint-Working Site of Palaeolithic date in the Medway Valley at Rochester, Kent, with Notes on the Drift-stages of the Medway. *Proc. Prehist. Soc. E. Anglia*, vol. iv, Pt. ii, p. 133.

DEWEY, H. and C. E. N. BROMEHEAD. 1924. The Geology of the Country around Dartford. *Mem. Geol. Surv.*

HUTCHINGS, G. E. 1925. The River Deposits of the Lower Medway Basin. *Proc. Geol. Assoc.*, vol. xxxvi, p. 419.

TOPLEY, W. 1875. The Geology of the Weald. *Mem. Geol. Surv.*

WHITAKER, W. 1872. The Geology of the London Basin. *Mem. Geol. Surv.*, vol. iv.

WOOLDRIDGE, S. W. 1923. The Minor Structures of the London Basin. *Proc. Geol. Assoc.*, vol. xxxiv, p. 175.

—— 1928. The 200-foot Platform in the London Basin. *Proc. Geol. Assoc.*, vol. xxxix, p. 1.

Chapter XI

ECONOMIC GEOLOGY

CEMENT, LIME AND WHITING

THE JUXTAPOSITION of Chalk and large alluvial deposits, both in the Thames and Medway valleys, has led to the establishment of an extensive cement manufacturing industry. The large chalk-pits near Cliffe, Frindsbury and Strood, those south-west of Rochester, and others on both east and west banks of the Medway, are all excavations for chalk for cement manufacture. Some, particularly on the east side of the Medway, have been derelict for many years, but others are still in full production (1950). Clay materials are obtained largely from alluvial muds, but around Snodland the Gault has also been worked. In addition to cement, products from the Chalk include lime and whiting; indeed the Upper Chalk tract in particular contains a great number of chalk-pits, many of them very old and disused, but a few still in work around Gillingham, Rainham and Sittingbourne.

BRICKMAKING

Bricks have been made at many localities over a period of a great many years, largely from brickearth deposits and weathered Thanet Beds. Rarely London Clay has been dug to mix with the Thanet Beds. Around Otterham Quay and Upchurch, and again east of Murston, much of the brickearth has been worked out, but a number of brickworks still operate both north and south of the Watling Street around Newington, Sittingbourne and Bapchild, and at Hoo.

Sand for sand-lime bricks is dug from Lower Tertiary beds at Upnor, and from the Folkestone Beds at Ham Hill, near Snodland. Bricks were formerly made from the Gault south of Burham.

SAND AND GRAVEL

The Low Terrace gravel deposits are comparatively important sources of sand; and gravel pits about a quarter of a mile west of Queens Farm, west of Higham or Church Street, expose up to 20 ft of gravel; near the Uralite Works another pit is 15 ft deep, while east of this a third pit is 22 ft deep, and its floor is 12 ft below the level of the adjacent alluvial tract. Extensive gravel deposits in the Low Terrace at Hoo are worked beneath brickearth (p. 141). Beneath the alluvium of the Medway, gravels of the Buried Channel are sufficiently thick and extensive to be dredged south of Snodland.

Most of the Terraced River Gravels above the Low Terrace are thin, and are only worked intermittently in shallow pits, indeed the great majority of these pits are now disused, as are pits up to 8 ft deep in the Isle of Grain.

The angular flint gravel underneath the brickearth in the dry valleys, and flints washed from the brickearth at brickworks, have all been used as road-making material in the past, but little is now dug.

Small quantities of gravel have been obtained from time to time from pits here and there in hillwash, and on occasion from the Clay-with-flints, but the material is of poor and uneven quality. West of Cuxton a good deal was formerly obtained from the stony head deposits in the floor of the valley. Sarsens of local origin have been extracted from the Clay-with-flints or other beds and broken up for local use as road-metal or ornamental stone, as for instance near Walderslade.

AGRICULTURE

The differing nature of the soils of the area has been one of several factors strongly influencing agriculture (*see* Hall and Russell 1911). The open texture of brickearth is particularly favourable to the cultivation of tree and bush fruits, and the presence of large areas of brickearth around Sittingbourne has been one of several reasons for that town having been a centre of the fruit-growing industry since the time of Henry VIII. Head deposits overlying Chalk produce land of higher agricultural status than does the bare chalk, and strong contrasts between areas of high and low fertility arising from this cause are commonly to be seen on the Chalk outcrop, instanced by the bottom and sides of a dry valley near Cuxton (Plate IIB).

In the area between the Thames and the Medway estuaries utilisation of the land is markedly dependent upon the soils derived from the different geological formations. The outlier of London Clay and Reading Beds at Shorne is largely under woodland, but the surrounding Chalk and Thanet Beds country is mainly arable land. The light easily worked loams that develop on the Lower Tertiary beds south of Cliffe and Cooling have attracted a centre of intense market gardening. In contrast, the adjacent bare outcrop of London Clay around Great Chattenden Wood and Decoy Farm is either woodland or grassland, while the lighter soils of the head-covered London Clay and gravel tracts to the east support mixed arable and market garden agriculture. Fruit orchards cover much of the brickearth area around Hoo.

WATER SUPPLY

The whole of the Chatham district is dependent on underground sources for its piped water supply, the great bulk of which is derived from the Chalk. Numerous Chalk wells—domestic, industrial, and for public waterworks—are distributed over the Chalk outcrop, more particularly the northern part through which runs the Watling Street, where hydrogeological conditions are more favourable to natural underground storage than they are on the higher ground nearer the Chalk escarpment to the south; and also over the Eocene outcrop where chalk is reached under not too heavy cover to affect adversely its yielding capacity.

Local water supply demands on the Chalk are considerable, both by public waterworks and by industry, each taking several million gallons daily. There is some evidence that in the neighbourhood of tidal waters overpumping has allowed an inflow of saline water.

In the Sheppey district, both on the Isle of Sheppey and on the alluvial tract adjoining it, farm supplies have been obtained from boreholes through London Clay into the sandy and pebbly beds of the Woolwich and Blackheath Beds, and the Thanet Beds. These sandy beds almost certainly contribute to some of the wells which enter the immediately underlying Chalk.

The great local demand for water has led to the exploration of the deep-seated Lower Greensand, lying in places up to 1300 ft below the ground surface.

In some instances boreholes in the Lower Greensand, notably in the neighbourhood of Chatham, have given moderate yields, but the considerable variation from place to place in the lithological character of the Lower Greensand at depth, as evidenced by existing boreholes (p. 20), shows the formation to be far from dependable, and a number of these deep holes have yielded no, or practically no supply. The prospects, however, improve southward towards the outcrop and the best supplies are obtained from the Folkestone Beds.

A number of records of local wells were published by Whitaker (1909) with geological classifications of strata, and further coverage of well-records in the area is presented by Cooling and others (1964). These and later records, usually offering data fuller than in the published accounts, are filed in the collection of records in the Hydrogeological Department of the Institute of Geological Sciences. F.H.E., H.G.D., S.C.A.H.

REFERENCES

COOLING, C. M. and others. 1964. Records of Wells in the area of New Series One-Inch (Geological) Chatham (272) Sheet, *Wat. Supply Pap. Geol. Surv. Gt Br. Well Catalogue Ser.*

HALL, A. D. and E. J. RUSSELL. 1911. *Report on the Agriculture and Soils of Kent, Surrey and Sussex.* Board of Agriculture and Fisheries.

WHITAKER, W. 1909. Water Supply of Kent. *Mem. Geol. Surv.*

Appendix

INVESTIGATION OF THE CLIFFE STRUCTURE IN 1959–61

THE FOLDING is expressed at the surface as an east–west pericline, of late Tertiary age, on the dip-slope of the North Downs. It is one of a number of such structures in the Thames Estuary region.

In 1959 the Gas Council commenced an investigation of the structure as a possible underground reservoir for gas storage. The study was twofold; firstly to prove closure and secondly to examine the thickness and reservoir properties of the Lower Greensand. The late Professor V. C. Illing acted as consultant geologist and the boreholes were drilled by the BP Exploration Company Limited. Geophysical logging of the boreholes was carried out by Schlumberger.

The early boring at Cliffe Marshes (*see* pp. 11, 22, 24, 29 and Whitaker 1908, pp. 108, 382) had recorded a thick Chalk and Gault sequence overlying 96 ft of Lower Greensand which rested on Silurian mudstones. Inadequacies in the drillers' log left some doubt as to the true thickness of the Lower Greensand (*see* p. 22).

During the period 1959–61 the Gas Council drilled 10 boreholes near East Tilbury (Essex) and Cliffe (Kent) to investigate the structure and its Lower Greensand development. (A projected No. 4 borehole was not drilled.) Cores were taken from the lower part of the Gault, the Lower Greensand and the underlying strata; these were Oxford Clay except in Boreholes 10 and 11, where presumed Old Red Sandstone was found. Geological Survey officers logged the cores and collected representative sets of lithological samples and fossils, which are now stored in the Borings and Palaeontological Departments (*see* p. 152). The logs of the upper parts of the boreholes were compiled by BP geologists from examination of chipping samples and the geophysical logs. A number of uncored boreholes were also drilled for further geophysical tests to elucidate the structure.

The results of the borings are presented in brief tabular form below, with the data from the Cliffe Marshes (1907) borehole for comparison. Depths are given to the nearest foot below Rotary Table Elevation, which was approximately 5 ft above the ground surface.

The investigation demonstrated the closure of the Cliffe Structure, but also showed that it was of very low amplitude. The Lower Greensand proved to be thinner and more variable than had been anticipated, and while it showed some promise as a reservoir rock, the fact that it rested on presumed Old Red Sandstone in boreholes 10 and 11 was an unfavourable factor. Fig. 8 shows sketch structural contours drawn on the top of the Lower Greensand and illustrates the general parallelism of the structure at depth with that at the surface as indicated by contours drawn on the base of the Tertiary formations (*see also* Fig. 3.

In a recent study of the stratigraphy of the Gault of the Thames Estuary region, H. G. Owen (*in press*) has suggested that the Oxford Clay proved in

TABULATED DATA FROM CLIFFE BOREHOLES

(Depths in feet below R.T.E.)

BOREHOLE CLIFFE NO. I.G.S. RECORD NO.	1 (272/269)	2 (272/272)	3 (271/445)	5 (272/268)	6 (272/270)	7 (272/271)	8 (272/278)	9 (272/273)	10 (272/274)	11 (272/275)	Cliffe Marshes (272/236)
Nat. Grid. Ref.	72457626	74717613	68057619	70667489	68907715	70687678	71447506	70347526	70837371	71767376	71887852
Date	1959	1960	1959	1959	1959	1960	1961	1960	1960	1960	1907
Rotary Table Elevation in feet (approx. 5 ft above Ground Level)	+10·8 OD	+24·4 OD	+23·6 OD	+9·3 OD	+9·3 OD	+9·0 OD	+10·4 OD	+9·5 OD	+8·3 OD	+13·4 OD	+c.12
Alluvium and Made Ground	to 79	—	to 90	to 54	—	to 65	to c.25	to 48	to 43	to c.20	to 43
Gravel	—	—	—	to 66	to 12	to 84	—	to 70		—	to 77
Lower London Tertiaries	—	—	—	—	—	—	to c.48	—	to 118	to 130	—
Chalk	to 620	to 691	to 689	to 760	to 687	to 625	to 740	to 744	to 792	to 808	to 733
Gault	to 808	to 867	to 874	to 947	to 884	to 808	to 929	to 926	to 977	to 993	to 941
Lower Greensand	to 822	to 889	to 890	to 964	to 900	to 822	to 942	to 949	to 991	to 998	to 1037
Oxford Clay	to 877*	to 949*	to 940*	to 1030*	to 920*	to 870*	to 985*	to 992*	—	—	—
Old Red Sandstone	—	—	—	—	—	—	—	—	to 1037*	to 1035*	—
Silurian	—	—	—	—	—	—	—	—	—	—	to 1072
Coring Intervals	780–873	844–940	850–940	778– 788 852– 878 900–1030	840–920	780–870	899–960 980–985	910–971	955–1014 1031–1037	897– 974 990–1005 1030 –1035	—
Specimen numbers in I.G.S. Borings and Palaeontological Depts.	Bs 7481 –7624	Bt 4470 –4547	Bs 7120 –7280	WA 2219 –2300	Bs 6935 –7119	Bt 4751 –4890	BDA 6419 –6538	Bt 4667 –4750	Bt 7268 –7389	Bv 1039 –1318	Zi 4726–35 GSM 23115–6 (Silurian only)

*Final Depth

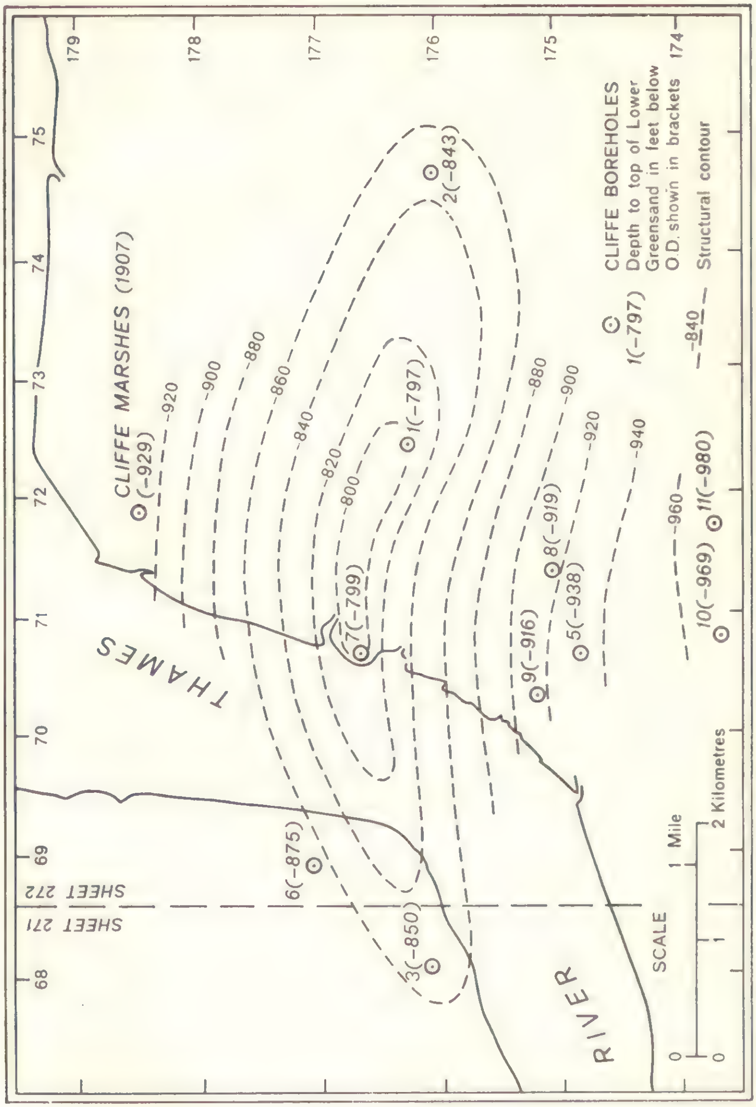


FIG. 8. *Structural contours on the top of the Lower Greensand at Cliffe.*

Contour interval 20 ft, depths in feet below Ordnance Datum. National Grid co-ordinates are marked around the edge of the map.

Cliffe Boreholes Nos. 1, 2, 3, 5, 6, 7, 8 and 9 is preserved in a fault-bounded, approximately east–west, graben between the presumed Old Red Sandstone proved in Cliffe Boreholes 10 and 11 and the Silurian of the Cliffe Marshes (1907) Borehole. This study, taking account of previous work in Essex and Kent, and including Dr. Owen's own determinations of the fossils collected by Geological Survey officers from the Cliffe cores, shows that the Lower Gault is generally absent or reduced to the north of the presumed graben, but is typically developed south of it. It is inferred on this basis that the northern boundary fault of the graben was active up to the end of Lower Gault times. A similar structure preserving Oxford Clay in a graben overlain by Wealden sediments has been described from the Tilmanstone area of the Kent Coalfield (Plumptre 1959), where a graben seems to have resulted from posthumous movement on the Hercynian faults of the coalfield in late-Jurassic times.

The following general descriptions based on detailed logs of the cores are included for information.

(a) *Gault.* Generally a mid blue-grey calcareous mudstone, occasionally silty or glauconitic, with bands of phosphatic nodules; molluscan and other fossils are abundant at certain levels. For a more detailed account of the stratigraphical palaeontology *see* Owen (*in press*); a short description of the beds at the junction with the Lower Greensand is given herewith as follows. In most of the boreholes the base of the Gault becomes sandy and glauconitic, with phosphatic nodules and small rounded quartz pebbles, in its lowest 2 or 3 ft. In Cliffe Boreholes Nos. 1, 2, 3, 5, 7, and 8 this rests on 1 to 1½ ft of hard, fine, pale calcareous sandstone with pebbles of shale and sandstone and some phosphatic nodules; this is here taken to mark the top of the Lower Greensand, following the classification of the Chatham Dockyard Borehole (272/6b) by Lamplugh (1923, p. 16. *See also* p. 21 this memoir). It is probable that all or part of these junction beds is referable to the *mammillatum* Zone and palaeontologically may be grouped therefore with the Lower Greensand (Casey 1961), but to preserve uniformity with the (lithological) classification adopted in this memoir, the junction has been retained as described and mapped at outcrop.

(b) *Lower Greensand.* With the hard calcareous bed described above included, from 5 to 23 ft of Lower Greensand are present in the Cliffe Structure. Generally the upper two-thirds of the formation are friable or free-running, fine, pale greenish sand with some glauconite; the lower portion tends to include more clayey sands and some thinner hard sandstone beds. Palaeontological work by Dr. R. Casey has demonstrated the presence of equivalents of the Folkestone Beds and Sandgate Beds in some cores; it is not, however, practicable to apply such classification throughout on account of the lateral variability and marked thinning of the Lower Greensand under deep cover north of its outcrops in North Kent. No evidence for the presence of Hythe Beds or Atherfield Clay has been found.

(c) *Oxford Clay.* The junction with the Lower Greensand is sharp and erosional, where clearly visible, but no basal conglomerate is present. Lithologically the formation, as seen, comprises olive grey calcareous mudstones, commonly pyritous, occasionally fossiliferous and frequently showing fine bioturbation. Several thin hard layers of cementstone (calcareous siltstone) have been noted. Owen (*in press*) records ammonites indicating the *praecordatum* subzone of the *mariae* Zone of the Oxfordian.

(d) Presumed *Old Red Sandstone.* In Boreholes 10 and 11 the Lower Greensand rests with a sharp junction on strata of pronounced 'Old Red Sandstone' facies including fine, red and green tinged, micaceous, current-bedded sandstones with some plant debris and red and green marls. No palaeontological proof of age is available, but the regional evidence suggests that these rocks are of Devonian age.

E.R.S.-T.

REFERENCES

CASEY, R. 1961. The Stratigraphical Palaeontology of the Lower Greensand. *Palaeontology*, **3,** 487–621.

LAMPLUGH, G. W., F. L. KITCHIN and J. PRINGLE. 1923. The Concealed Mesozoic Rocks in Kent. *Mem. Geol. Surv.*

OWEN, H. G. (*in press.*) The Stratigraphy of the Gault in the Thames Estuary and its bearing on the Mesozoic Tectonic history of the area. *Proc. Geol. Assoc.*

PLUMPTRE, J. H. 1959. Underground Waters of the Kent Coalfield. *Trans. Inst. Min. Engrs*, **119,** 155–69.

WHITAKER, W. 1908. Water Supply of Kent. *Mem. Geol. Surv.*

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